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FIRST QUARTERLY REPORT

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Special AROD System Studies

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First Quarterly Report for NASA Contract No. NAS 8-11050

PREPARED FOR

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Abstract

This document is the First Quarterly Report for Contract No. NAS 8-11050, summarizing three months of work by the IBM Corporation for NASA. Progress on two tasks of the Special AROD System Studies contract—the Computer Interface Investigation and the Oceanborne Transponders analysis—is reported herein; work on the other tasks for the contract has been deferred at the request of the Contracting Officer's Representative.

Results of the Computer Interface Investigation (Section 1) are presented in three categories: computer requirements; launch trajectory error analysis; and the AROD/computer interface. A detailed derivation of the equations necessary to convert the basic AROD measurements, range, and range rate, to position and velocity provides the foundation for a preliminary determination of the computer requirements for all AROD computations. Based upon the characteristics of the advanced Saturn computer, a computation time of 0.2 ± .1 seconds has been estimated for the AROD operations. The launch trajectory error analysis presents an extensive evaluation of the Geometrical Dilution of Precision (GDOP) associated with the utilization of AROD in the Atlantic Missile Range. The AROD/computer interface discussion outlines an approach to the implementation of this interface and discusses some unresolved issues.

In Section 2, Oceanborne Transponders, a preliminary analysis of the specific problem areas involved in the establishment of a network of oceanborne transponders is presented. Emphasis is upon the use of taut line mooring and/or acoustic ranging equipment to keep relatively stationary a transponder-carrying buoy. Design considerations for such buoys are discussed.

In each section plans for the next quarterly reporting period are presented.

CONTENTS

Page

ILLUSTRATIONS

TABLES

Section 1

COMPUTER INTERFACE INVESTIGATION

The computer interface investigation has been organized into three areas: a determination of the computational and storage requirements for performing the AROD calculations; a computer analysis of the errors associated with representative Saturn trajectories; and a discussion of the considerations involved in implementing the AROD/computer interface. These areas are discussed in paragraphs 1.1, 1.2, and 1.3 respectively.

1.1 COMPUTER REQUIREMENTS

The computer requirements problem can be divided into two areas: basic computations and auxiliary computations. The basic computation area refers to the calculation of the vehicle position and velocity from transponder locations and the range and range rate data. All other computational requirements are grouped under the auxiliary computations heading. Paragraphs 1.1.1 and 1.1.2 discuss the work to date on these problems.

1.1.1 Basic Computations

1.1.1.1 Introduction

In the following paragraphs, mathematical solutions for the AROD position and velocity navigation equations are developed and explained. The position and inertial velocity components of three AROD transponder stations (including the effect of earth's rotation), and the measured relative range and range rate to each station are assumed to be known at the time of measurement. All solutions developed here are later reduced to math flow diagram form, to facilitate estimation of computer requirements.

Vehicle position and velocity components are solved in the same inertial coordinate system in which the station coordinates are supplied — for example, geocentric inertial or topocentric inertial. Station coordinates may be easily transformed and translated from an inertial geocentric system to an inertial topocentric system. The position equations which must be solved first are a set of second order non-linear equations, while the velocity equations, using the vehicle position as a known input, are a set of three linear equations in three unknowns.

1.1.1.2 Position Computations

Three different methods of solution are proposed for the position equations. Each of these assumes a current knowledge of station position (and velocity) coordinates in the appropriate coordinate system at the (given) time of measurement. Thus, a first step common to all position solutions is the updating of station position coordinates (see, for example, equation 1.34a Sec. 1.1.1.3).

A direct closed form analytical solution was developed for the AROD position equations by taking advantage of the symmetry of the equations, noting that the second order terms can be eliminated with certain algebraic manipulations. The danger in such an operation is that some of the roots may be shifted (or even eliminated) from the real values. This can be avoided by carefully substituting back into the original equations after each variable has been eliminated, and by using each of the constraint equations in the analysis. It is felt that this has been accomplished here.

In general, the position equations give two points for the missile's inertial position — one of which will probably fall inside the surface of the earth, while the other solution will be the meaningful one. This can be seen from the mathematics of solving equations 1.1, 1.2, and 1.3 herein, the solution of which is the intersection of three spheres, most generally a pair of points. For this reason, one set of roots must be eliminated.

For computer sizing purposes, the set of computations which must be performed by the on-board computer is presented in math flow diagram form at the end of this section. There are three position and velocity computations which must be performed for each of three stations involved in a measurement at a particular time. Values for station latitude (ψ), station radius from the geocenter (R), and initial inertial station longitude (λ_0), must be stored for each station in the network.

The direct solution to the position navigation equations will be derived using figure 1.1 to define the nomenclature:

The three Position Navigation Equations may be written as:

$$(x-x_1)^2 + (y-y_1)^2 + (z-z_1)^2 - r_1^2 = 0 \qquad (1.1)$$

$$(x-x_2)^2 + (y-y_2)^2 + (z-z_2)^2 - r_2^2 = 0 \qquad (1.2)$$

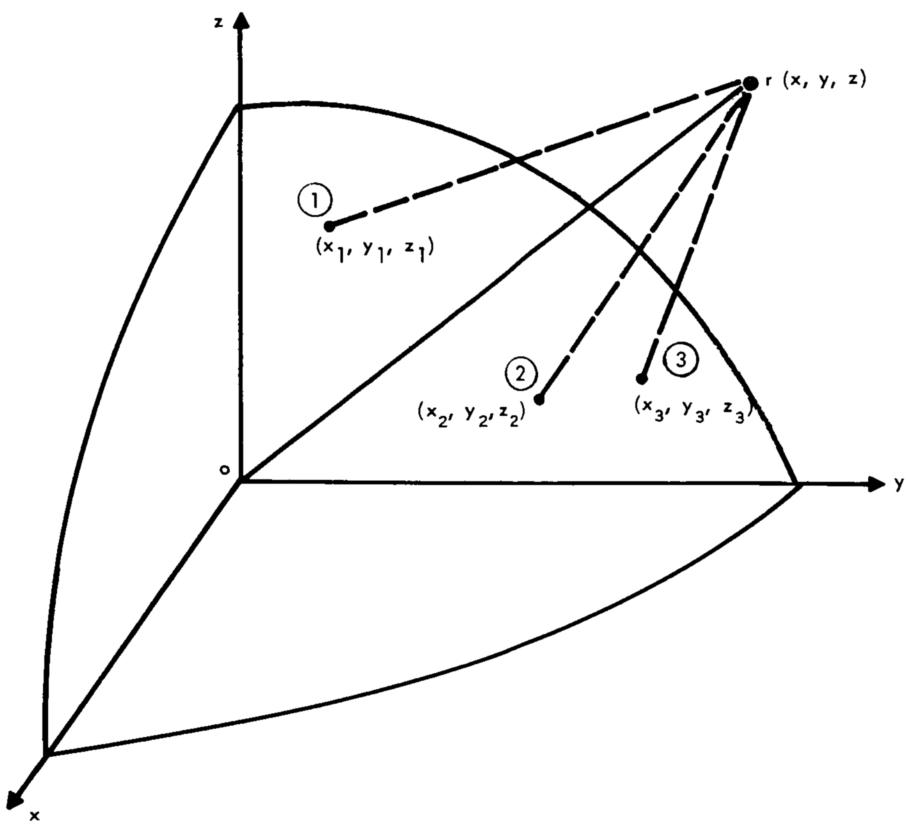
$$(x-x_3)^2 + (y-y_3)^2 + (z-z_3)^2 - r_3^2 = 0 \qquad (1.3)$$

where x, y, z must be determined, all other quantities are known or measured and considered constant.

Expand equations 1.1, 1.2, and 1.3 as:

$$x^2 + y^2 + z^2 - 2x_1x - 2y_1y - 2z_1z + x_1^2 + y_1^2 + z_1^2 - r_1^2 = 0 \qquad (1.4)$$

$$x^2 + y^2 + z^2 - 2x_2x - 2y_2y - 2z_2z + x_2^2 + y_2^2 + z_2^2 - r_2^2 = 0 \qquad (1.5)$$



z, y, z	-geocentric inertial reference frame
$r_1, r_2, r_3,$	-vehicle to stations ①, ②, ③, - relative range
$\dot{r}_1, \dot{r}_2, \dot{r}_3,$	-vehicle to stations ①, ②, ③, -relative range rate
x_i, y_i, z_i	-i = 1, 2, 3 location of stations ①, ②, ③
$\vec{r} = \hat{i}\,x + \hat{j}\,y + \hat{k}\,z$	-vehicle instantaneous range vector
$\dot{\vec{r}} = \hat{i}\,\dot{x} + \hat{j}\,\dot{y} + \hat{k}\,\dot{z}$	-vehicle instantaneous velocity vector

Figure 1.1. GEOMETRY AND NOMENCLATURE

$$x^2 + y^2 + z^2 - 2x_3x - 2y_3y - 2z_3z + x_3^2 + y_3^2 + z_3^2 - r_3^2 = 0 \qquad (1.6)$$

Let $K_1 = x_1^2 + y_1^2 + z_1^2 - r_1^2$

$K_2 = x_2^2 + y_2^2 + z_2^2 - r_2^2$

$K_3 = x_3^2 + y_3^2 + z_3^2 - r_3^2$

eq 1.4 - eq 1.5: $(-2x_1 + 2x_2)x + (-2y_1 + 2y_2)y + (-2z_1 + 2z_2)z + K_1 - K_2 = 0$

eq 1.4 - eq 1.6: $(-2x_1 + 2x_3)x + (-2y_1 + 2y_3)y + (-2z_1 + 2z_3)z + K_1 - K_3 = 0$

Note: eq 1.5 - eq 1.6 is redundant since

eq 1.5 - eq 1.6 = eq 1.4 - eq 1.6 - (eq 1.4 - eq 1.5) = - eq 1.6 + eq 1.5

Rewrite (eq 1.4 - eq 1.5) and (eq 1.4 - eq 1.6) as:

eq 1.4 - eq 1.5 $\quad \alpha x + \beta y + \delta z + \epsilon = 0$

eq 1.4 - eq 1.6 $\quad \gamma x + \lambda y + \mu z + \rho = 0$

where

$\alpha = -2x_1 + 2x_2$	$\gamma = -2x_1 + 2x_3$
$\rho = -2y_1 + 2y_2$	$\lambda = -2y_1 + 2y_3$
$\delta = -2z_1 + 2z_2$	$\mu = -2z_1 + 2z_3$
$\epsilon = K_1 - K_2$	$\rho = K_1 - K_3$

Let

$$x = -\frac{\beta}{\alpha} y - \frac{\delta}{\alpha} z - \frac{\epsilon}{\alpha}$$

From the eq 1.4 - eq 1.5 expression,

$$x = ay + bz + c$$

where

$$a = -\frac{\beta}{\alpha}\ ; \quad b = -\frac{\delta}{\alpha}\ ; \quad c = -\frac{\epsilon}{\alpha}$$

and

$$x^2 = a^2y^2 + b^2z^2 + 2abyz + 2acy + 2bcz + c^2$$

Substitute x and x^2 back into eq 1.4, eq 1.5, and eq 1.6 to get eq 1.7, eq 1.8, and eq 1.9:

$$(a^2y^2 + b^2z^2 + 2abyz + 2acy + 2bcz + c^2) + y^2 + z^2$$
$$- 2x_1(ay + bz + c) - 2y_1y - 2z_1z + K_1 = 0$$

$$y^2(a^2 + 1) + z^2(b^2 + 1) + 2abyz + y(2ac - 2ax_1 - 2y_1) \tag{1.7}$$
$$+ z(2bc - 2bx_1 - 2z_1) + c^2 - 2cx_1 + K_1 = 0$$

$$y^2(a^2 + 1) + z^2(b^2 + 1) + 2abyz + y(2ac - 2ax_2 - 2y_2) \tag{1.8}$$
$$+ z(2bc - 2bx_2 - 2z_2) + c^2 - 2cx_2 + K_2 = 0$$

$$y^2(a^2 + 1) + z^2(b^2 + 1) + 2abyz + y(2ac - 2ax_3 - 2y_3) \tag{1.9}$$
$$+ z(2bc - 2bx_3 - 2z_3) + c^2 - 2cx_3 + K_3 = 0$$

Now solve for $y = f(z)$ by performing eq 1.7 - eq 1.9 or eq 1.8 - eq 1.9 to include the effects of the third equation with the coordinates of the third station (x_3, y_3, z_3). Notice that in the expression $x = ay + bz + c$, a, b, and c do not include the third station coordinates or the effect of the third equation. If the final solution is to be valid $y = f(z)$ must be obtained by including this constraint.

eq 1.7 - eq 1.9

$$y(-2ax_1 - 2y_1 + 2ax_3 + 2y_3) + z(-2bx_1 - 2z_1 + 2bx_3 + 2z_3)$$

$$-2c(x_1 - x_3) + K_1 - K_3 = 0$$

or

$$K_4 y + K_5 z = K_6$$

where

$$K_4 = -2a x_1 - 2y_1 + 2a x_3 + 2y_3$$

$$K_5 = -2b x_1 - 2z_1 + 2b x_3 + 2z_3$$

$$K_6 = K_3 - K_1 + 2c(x_1 - x_3);$$

$$y = K_7 z + K_8 \qquad K_7 = -K_5/K_4 \qquad K_8 = K_6/K_4$$

Substitute into the eq 1.8 expression:

$$(K_7^2 z^2 + 2 K_7 K_8 z + K_8^2)(a^2 + 1) + z^2(b^2 + 1) + 2abz(K_7 z + K_8)$$

$$+ (2ac - 2a x_2 - 2y_2)(K_7 z + K_8) + z(2bc - 2b x_2 - 2z_2)$$

$$+ K_2 + c^2 - 2c x_2 = 0$$

Simplifying,

$$z^2 \left[K_7^2 (a^2 + 1) + (b^2 + 1) + 2 K_7 ab\right] + z \left[2 K_7 K_8 (a^2 + 1)\right.$$

$$+ 2 K_8 ab + K_7(2ac - 2ax_2 - 2y_2) + (2bc - 2bx_2$$

$$\left.- 2z_2)\right] + \left[K_8^2 (a^2 + 1) + K_8 (2ac - 2a x_2\right.$$

$$\left.- 2y_2) + K_2 + c^2 - 2c x_2\right] = 0$$

which can be solved by the quadratic formula giving two roots in z

$$K_9 z^2 + K_{10} z + K_{11} = 0$$

$$z = \frac{- K_{10} \pm \sqrt{(K_{10})^2 - 4 (K_9) (K_{11})}}{2 K_9}$$

Thus

$$z' = \frac{- K_{10} + \sqrt{(K_{10})^2 - 4 (K_9) (K_{11})}}{2 K_9}$$

$$z'' = \frac{- K_{10} - \sqrt{(K_{10})^2 - 4 (K_9) (K_{11})}}{2 K_9}$$

where

$$K_9 = K_7^2 (a^2 + 1) + b^2 + 1 + 2 K_7 ab$$

$$K_{10} = 2 K_7 K_8 (a^2 + 1) + 2 K_8 ab + K_7 (2ac - 2ax_2 - 2y_2)$$
$$+ 2bc - 2b x_2 - 2z_2$$

$$K_{11} = K_8^2 (a^2 + 1) + K_8 (2ac - 2ax_2 - 2y_2) + K_2 + c^2 - 2cx_2$$

The two y roots can be found from

$$y' = K_7 z' + K_8$$

$$y'' = K_7 z'' + K_8$$

and the two x roots from

$$x' = a y' + b z' + c$$

$$x'' = a y'' + b z'' + c$$

In general the solution gives two points (x', y', z') and (x'', y'', z''), one of which accurately describes the vehicle's position and the other of which lies below the surface of the earth.

Thus

if $x'^2 + y'^2 + z'^2 < R^2$ eliminate x', y', z' as solution

if $x''^2 + y''^2 + z''^2 < R^2$ eliminate x'', y'', z'' as solution

where R is an input quantity taken to be the earth's radius.

Summary of Solution for Vehicle's Position

$$z' = \frac{-K_{10} + \sqrt{(K_{10})^2 - 4\,(K_9)\,(K_{11})}}{2\,K_9}$$

$$z'' = \frac{-K_{10} - \sqrt{(K_{10})^2 - 4\,(K_9)\,(K_{11})}}{2\,K_9}$$

$$y' = K_7\, z' + K_8$$

$$y'' = K_7\, z'' + K_8$$

$$x' = ay' + bz' + c$$

$$x'' = ay'' + bz'' + c$$

where:

$$K_9 = K_7^2\,(a^2 + 1) + b^2 + 1 + 2\,K_7\,ab$$

$$K_{10} = 2\,K_7\,K_8\,(a^2 + 1) + 2\,K_8\,ab + K_7\,(2\,ac - 2\,ax_2 - 2y_2) + 2bc - 2bx_2 - 2z_2$$

$$K_{11} = K_8^2\,(a^2 + 1) + K_8\,(2ac - 2ax_2 - 2y_2) + K_2 + c^2 - 2cx_2$$

$$K_7 = -K_5/K_4 \qquad K_8 = K_6/K_4$$

$$K_4 = -2ax_1 - 2y_1 + 2ax_3 + 2y_3$$

$$K_5 = -2bx_1 - 2z_1 + 2bx_3 + 2z_3$$

$$K_6 = K_3 - K_1 + 2c(x_1 - x_3)$$

$$K_1 = x_1^2 + y_1^2 + z_1^2 - r_1^2$$

$$K_2 = x_2^2 + y_2^2 + z_2^2 - r_2^2$$

$$K_3 = x_3^2 + y_3^2 + z_3^2 - r_3^2$$

$$a = (y_1 - y_2) / (x_2 - x_1); \; b = (z_1 - z_2) / (x_2 - x_1);$$

$$c = (K_2 - K_1)/2(x_2 - x_1)$$

Elimination of one set of roots:

If $x'^2 + y'^2 + z'^2 < R^2$, eliminate x', y', z'

If $x''^2 + y''^2 + z''^2 < R^2$, eliminate x'', y'', z''

R – input constant - nominal earth radius

Check on solution:

Solving x from the (eq. 1.4 - eq. 1.6) expression,

$$x = -\frac{\lambda}{\gamma} y - \frac{\mu}{\gamma} z - \frac{\rho}{\gamma}$$

$$x = \left(\frac{y_1 - y_3}{x_3 - x_1}\right) y + \left(\frac{z_1 - z_3}{x_3 - x_1}\right) z + \frac{K_1 - K_3}{2\,(x_1 - x_3)}$$

should be identically equal to x obtained from (eq. 1.4 - eq. 1.5).

1.1.1.2.2 Method of Differential Correction

The second method investigated for solving the AROD position equations employs differential corrections. In general, solving a set of non-linear simultaneous equations involves an iterative procedure where, it is hoped, successive guesses at the roots will eventually converge to the true answer. The method of differentially correcting the assumed roots is presented here with the specific application to the AROD problem given first followed by a theoretical development of the general method.

For this method an a priori estimate of the solution must be available, such as an accurate nominal trajectory which forms the basis for the first set of guessed roots. It is estimated that a minimum of three iterations will usually be required for convergence to a solution; if convergence does not occur a new initial guess will have to be made and the procedure repeated. Certain convergence tests are available but it is simpler to examine the errors and note whether they are growing smaller.

Solution to Position Navigation Equation
By Differential Correction Procedure

Write equations in expanded form as:

$$f_1 = x^2 + y^2 + z^2 - 2x_1 x - 2y_1 y - 2z_1 z + x_1^2 + y_1^2 + z_1^2 - r_1^2 = 0 \quad (1.10)$$

$$f_2 = x^2 + y^2 + z^2 - 2x_2 x - 2y_2 y - 2z_2 z + x_2^2 + y_2^2 + z_2^2 - r_2^2 = 0 \quad (1.11)$$

$$f_3 = x^2 + y^2 + z^2 - 2x_3 x - 2y_3 y - 2z_3 z + x_3^2 + y_3^2 + z_3^2 - r_3^2 = 0 \quad (1.12)$$

Let

$$K_1 = x_1^2 + y_1^2 + z_1^2 - r_1^2$$

$$K_2 = x_2^2 + y_2^2 + z_2^2 - r_2^2$$

$$K_3 = x_3^2 + y_3^2 + z_3^2 - r_3^2$$

then

$$f_1 = x^2 + y^2 + z^2 - 2x_1 x - 2y_1 y - 2z_1 z + K_1 = 0 \quad (1.13)$$

$$f_2 = x^2 + y^2 + z^2 - 2x_2 x - 2y_2 y - 2z_2 z + K_2 = 0 \quad (1.14)$$

$$f_3 = x^2 + y^2 + z^2 - 2x_3x - 2y_3y - 2z_3z + K_3 = 0 \tag{1.15}$$

Assuming prior knowledge of approximate vehicle position, take as first guess $(x_{g_1}, y_{g_1}, z_{g_1})$ for the first iteration.

Since, in general, these are not the correct roots, substituting these values into eqs (1.13, 1.14, 1.15) will yield residuals ϵ_{g_1}, ϵ_{g_2}, ϵ_{g_3} given by:

$$f_1 = x_{g_1}^2 + y_{g_1}^2 + z_{g_1}^2 - 2x_1x_{g_1} - 2y_1y_{g_1} - 2z_1z_{g_1} + K_1 = \epsilon_{g_1}$$

$$f_2 = x_{g_1}^2 + y_{g_1}^2 + z_{g_1}^2 - 2x_2x_{g_1} - 2y_2y_{g_1} - 2z_2z_{g_1} + K_2 = \epsilon_{g_2}$$

$$f_3 = x_{g_1}^2 + y_{g_1}^2 + z_{g_1}^2 - 2x_3x_{g_1} - 2y_3y_{g_1} - 2z_3z_{g_1} + K_3 = \epsilon_{g_3}$$

From the theory it can be shown that

$$-\epsilon_{g_1} = \frac{\partial f_1}{\partial x_g}\Delta x_1 + \frac{\partial f_1}{\partial y_g}\Delta y_1 + \frac{\partial f_1}{\partial z_g}\Delta z_1$$

$$-\epsilon_{g_2} = \frac{\partial f_2}{\partial x_g}\Delta x_1 + \frac{\partial f_2}{\partial y_g}\Delta y_1 + \frac{\partial f_2}{\partial z_g}\Delta z_1$$

$$-\epsilon_{g_3} = \frac{\partial f_3}{\partial x_g}\Delta x_1 + \frac{\partial f_3}{\partial y_g}\Delta y_1 + \frac{\partial f_3}{\partial z_g}\Delta z_1$$

or in matrix form

$$\begin{pmatrix} -\epsilon_{g_1} \\ -\epsilon_{g_2} \\ -\epsilon_{g_3} \end{pmatrix} = \begin{bmatrix} \frac{\partial f_1}{\partial x_y} & \frac{\partial f_1}{\partial y_g} & \frac{\partial f_1}{\partial z_g} \\ \frac{\partial f_2}{\partial x_g} & \frac{\partial f_2}{\partial y_g} & \frac{\partial f_2}{\partial z_g} \\ \frac{\partial f_3}{\partial x_g} & \frac{\partial f_3}{\partial y_g} & \frac{\partial f_3}{\partial z_g} \end{bmatrix} \begin{pmatrix} \Delta x_1 \\ \Delta y_1 \\ \Delta z_1 \end{pmatrix}$$

or

$$
\begin{pmatrix} \Delta x_1 \\ \Delta y_1 \\ \Delta z_1 \end{pmatrix} = \begin{bmatrix} \frac{\partial f_1}{\partial x_g} & \cdot & \cdot & \cdot & \frac{\partial f_1}{\partial z_g} \\ \cdot & \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \cdot & \\ \cdot & \cdot & \cdot & \cdot & \\ \frac{\partial f_3}{\partial x_g} & \vdots & \vdots & \vdots & \frac{\partial f_3}{\partial z_g} \end{bmatrix}^{-1} \begin{pmatrix} -\epsilon_{g_1} \\ -\epsilon_{g_2} \\ -\epsilon_{g_3} \end{pmatrix}
$$

Δx_1, Δy_1, Δz_1 form the basis for the next iteration where

$$x_{g_2} = x_{g_1} + \Delta x_1$$

$$y_{g_2} = y_{g_1} + \Delta y_1$$

$$z_{g_2} = z_{g_1} + \Delta z_1$$

The partials involved in the error matrix can be written out as follows:

$$\frac{\partial f_1}{\partial x_g} = 2x_g - 2x_1 \qquad \frac{\partial f_1}{\partial y_g} = 2y_g - 2y_1 \qquad \frac{\partial f_1}{\partial z_g} = 2z_g - 2z_1$$

$$\frac{\partial f_2}{\partial x_g} = 2x_g - 2x_2 \qquad \frac{\partial f_2}{\partial y_g} = 2y_g - 2y_2 \qquad \frac{\partial f_2}{\partial z_g} = 2z_g - 2z_2$$

$$\frac{\partial f_3}{\partial x_g} = 2x_g - 2x_3 \qquad \frac{\partial f_3}{\partial y_g} = 2y_g - 2y_3 \qquad \frac{\partial f_3}{\partial z_g} = 2z_g - 2z_3$$

x_{g_2}, y_{g_2}, z_{g_2} are the next guessed roots for the second iteration, etc. Convergence problems may exist for f's which are non-linear functions as in this case. It is <u>important</u> to have a good preliminary estimate of the roots.

Theoretical Development of Solution by Differential Correction

Suppose a problem is expressed in variables $q_1, q_2, q_3, \ldots q_n$ where, for example $q_1 = x$, $q_2 = y$, $q_3 = z$, etc.

The solution requires that

$$f_i (q_j) = 0; \quad i, j = 1, \ldots, n.$$

where there are a total of n simultaneous equations in n unknowns.

First guess a set of solution values, q_{g_j}, which lie in the neighborhood of the true solution. An evaluation of the functions $f_i (q_{g_j})$ will probably give a non-zero answer where

$$f_i (q_{g_j}) = \epsilon_{g_i}$$

It is desired to drive the ϵ_{g_i} to zero by making ℓ successive guesses on the q_j variables (e.g. $q_{1_j}, q_{2_j}, \ldots q_{\ell_j}$). If the first guessed values for the roots, q_{1_j}, are close to the actual q_j values then the number of guesses necessary to converge to a solution should be small.

Suppose that our next guess - or some subsequent guess, $q_{(g+1)j}$ eliminates the error, $\epsilon_{(g+1)_i}$,

$$f_i (q_{(g+1)_j}) = 0$$

where

$$q_{(g+1)_j} = q_{g_j} + \Delta q_j$$

Expanding $f_i (q_{g_j} + \Delta q_j) = 0$ in a Taylor Series about the point q_{g_j}, the previously guessed solution, and keeping only the first two terms of the expansion yields

$$f_i = (q_{g_j} + \Delta q_j) = f_i (q_{g_j}) + \frac{\partial f_i}{\partial q_j} \Delta q_j = 0$$

But $\quad f_i(q_{g_j}) = \epsilon_{g_i}$

Therefore, $\quad f_i(q_{g_j} + \Delta q_j) = \epsilon_{g_i} + \dfrac{\partial f_i}{\partial q_j} \Delta q_j = 0$

Solving the above equation for ϵ_{g_i} results in

$$-\epsilon_{g_i} = \frac{\partial f_i}{\partial q_j} \Delta q_j$$

or writing out the equations for $\quad i = 1, 2, 3$

$j = 1, 2, 3$

$$-\epsilon_{g_1} = \frac{\partial f_1}{\partial q_1} \Delta q_1 + \frac{\partial f_1}{\partial q_2} \Delta q_2 + \frac{\partial f_1}{\partial q_3} \Delta q_3$$

$$-\epsilon_{g_2} = \frac{\partial f_2}{\partial q_1} \Delta q_1 + \frac{\partial f_2}{\partial q_2} \Delta q_2 + \frac{\partial f_2}{\partial q_3} \Delta q_3$$

$$-\epsilon_{g_3} = \frac{\partial f_3}{\partial q_1} \Delta q_1 + \frac{\partial f_3}{\partial q_2} \Delta q_2 + \frac{\partial f_3}{\partial q_3} \Delta q_3$$

In matrix form,

$$\begin{pmatrix} -\epsilon_{g_1} \\ -\epsilon_{g_2} \\ -\epsilon_{g_3} \end{pmatrix} = \begin{bmatrix} \dfrac{\partial f_1}{\partial q_1} & \dfrac{\partial f_1}{\partial q_2} & \dfrac{\partial f_1}{\partial q_3} \\ \dfrac{\partial f_2}{\partial q_1} & \dfrac{\partial f_2}{\partial q_2} & \dfrac{\partial f_2}{\partial q_3} \\ \dfrac{\partial f_3}{\partial q_1} & \dfrac{\partial f_3}{\partial q_2} & \dfrac{\partial f_3}{\partial q_3} \end{bmatrix} \begin{pmatrix} \Delta q_1 \\ \Delta q_2 \\ \Delta q_3 \end{pmatrix}$$

or

$$(\Delta q_j) = \left(\frac{\partial f_i}{\partial q_j} \right)^{-1} (-\epsilon_{g_i})$$

where $\frac{\partial f_i}{\partial q_j}$ and ϵ_{g_i} are known

The Δq_j solved for are the differential corrections to the guessed set of roots q_{g_j}

If $f_i (q_{(g+1)_j}) = \epsilon_{(g+1)_j} \neq 0$

where $q_{(g+1)_j} = q_{g_j} + \Delta q_j$

the procedure must then be repeated to correct $q_{(g+1)_j}$.

The two general types of convergence are:

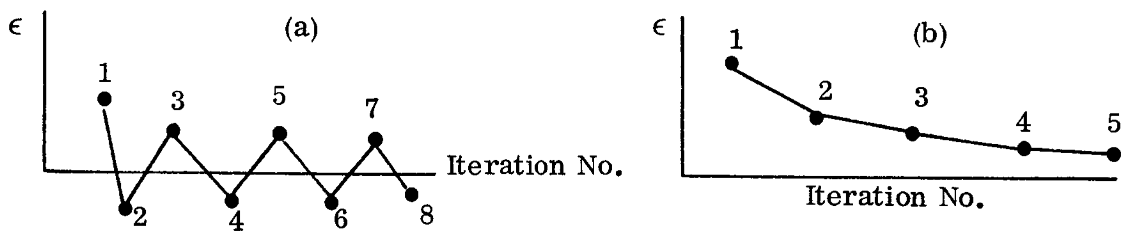


Figure 1.2. TYPES OF CONVERGENCE

Convergence may be speeded by multiplying Δq_j by <1, (Figure 1.2-a) and by >1 (Figure 1.2-b), thereby reducing the number of iterations.

1.1.1.2.3 "Analytic Geometry" Solution to AROD Position Equations

This paragraph outlines the third method for solving the AROD position equations; the method is based on analytic geometry considerations. By way of review, the equations for vehicle position (x, y, z) are

$$\left.\begin{aligned} (x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2 &= r_1^2 \\ (x - x_2)^2 + (y - y_2)^2 + (z - z_2)^2 &= r_2^2 \\ (x - x_3)^2 + (y - y_3)^2 + (z - z_3)^2 &= r_3^2, \end{aligned}\right\} \quad (1.16)$$

where r_1, r_2, r_3 are measured ranges to three ground stations having known coordinates (x_i, y_i, z_i), $i = 1,2,3$. Equations (1.16) define three spheres centered at the station sites and having radii r_1, r_2, r_3. Two of these spheres, say ① and ②, intersect in a circle; and two others, say ① and ③, intersect in another circle. These two circles then generally intersect in two points, which are common points to the three spheres and fix the vehicle position (one point is ambiguous and must be eliminated by a suitable test).

The solution proposed here for (x, y, z) may be summarized as follows:

a. Find the equation of the plane containing the circle of intersection of spheres ① and ②.

b. Find the equation of the plane containing the circle of intersection of spheres ① and ③.

c. Find the line of intersection of these two planes. This line must contain the two solution points for vehicle position, since

   1. it contains all points common to the two planes, and hence
   2. in a more restricted sense, it contains all points common to the two circles of intersection, namely the two possible vehicle positions.

d. Find the two points on this line at distance r_1 from (x_1, y_1, z_1); these are the desired solutions.

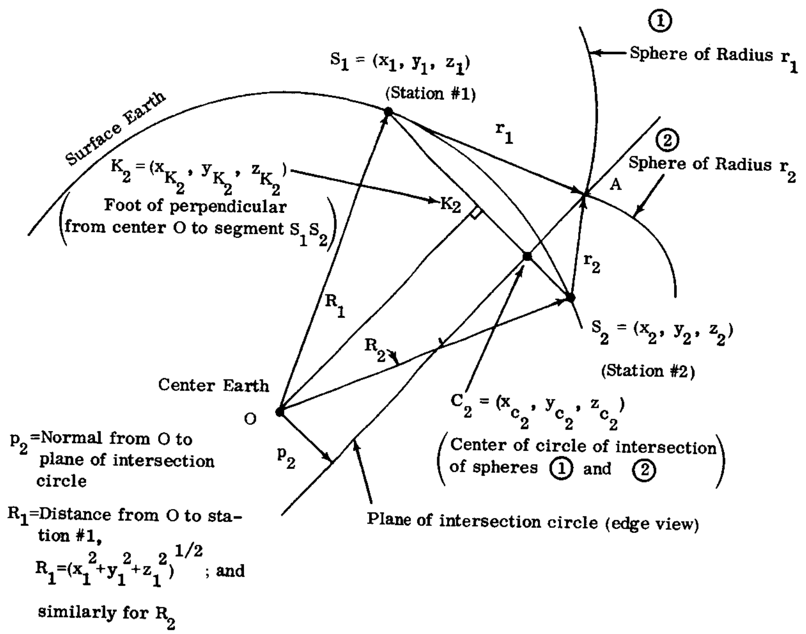


Figure 1.3. AROD POSITION FIX GEOMETRY

In Figure 1.3 the center C_2 of the circle of intersection of spheres (1) and (2) lies on the line of centers of the two spheres, i.e. the line joining the two stations 1 and 2. The plane determined by this circle contains C_2 and is normal to the line of centers S_1S_2. OK_2 is perpendicular to chord S_1S_2. The direction cosines and length of the segment K_2C_2 are equivalent to those of the normal p_2 from center earth to the plane. It is noted that K_2 does not necessarily bisect S_1S_2, since the two stations are in general at different distances from center earth (different site altitudes or nonspherical earth considerations, etc.)

The equation of the plane is obtained as follows:

In triangle S_1S_2A,

$$S_1S_2 = \left[(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2 \right]^{1/2} \tag{1.17}$$

$$\cos S_2S_1A = \frac{r_1^2 + (S_1S_2)^2 - r_2^2}{2r_1\,(S_1S_2)} \tag{1.18}$$

$$S_1C_2 = r_1 \cos S_2S_1A = \frac{r_1^2 + (S_1S_2)^2 - r_2^2}{2\,(S_1S_2)} \tag{1.19}$$

[Note S_1C_2 can be positive or negative]

coordinates of C_2:

$$\left.\begin{aligned} x_{C_2} &= x_1 + \frac{S_1C_2}{S_1S_2}(x_2 - x_1) \\ y_{C_2} &= y_1 + \frac{S_1C_2}{S_1S_2}(y_2 - y_1) \\ z_{C_2} &= z_1 + \frac{S_1C_2}{S_1S_2}(z_2 - z_1) \end{aligned}\right\} \tag{1.20}$$

Similarly in triangle OS_1S_2, knowing R_1 and R_2 (Figure 1.3) and S_1S_2 from angle OS_1S_2 can be found, hence segment S_1K_2, hence coordinates x_{K_2}, y_{K_2}, z_{K_2}, and

$$\begin{aligned} K_2C_2 &= \left[(x_{K_2} - x_{C_2})^2 + (y_{K_2} - y_{C_2})^2 + (z_{K_2} - z_{C_2})^2\right]^{1/2} \\ &\equiv p_2 \end{aligned} \tag{1.21}$$

Direction cosines of line segment from K_2 to C_2:

$$\left.\begin{aligned} \ell_2 &= (x_{C_2} - x_{K_2})/p_2 \\ m_2 &= (y_{C_2} - y_{K_2})/p_2 \\ n_2 &= (z_{C_2} - z_{K_2})/p_2 \end{aligned}\right\} \tag{1.22}$$

Equation of plane: $\ell_2 x + m_2 y + n_2 z = p_2$ (1.23)

Equation of plane containing circle of intersection of spheres 1 and 3

Geometry and formulation are analogous to Part a above, with all subscripts "2" being replaced by "3". There results the equation

$$\ell_3 x + m_3 y + n_3 z = p_3 \tag{1.24}$$

Line of intersection of the two planes

The line of intersection of planes (eq. 1.23) and (eq. 1.24) is found by first eliminating z, then eliminating y, between (eq. 1.23) and (eq. 1.24)

Eliminating z,

$$y = \frac{\ell_3 n_2 - \ell_2 n_3}{m_2 n_3 - m_3 n_2} x + \frac{p_2 n_3 - p_3 n_2}{m_2 n_3 - m_3 n_2} \tag{1.25}$$

$$\text{i.e., } y \equiv a_1 x + b_1 \tag{1.26}$$

Eliminating y,

$$z = \frac{\ell_2 m_3 - \ell_3 m_2}{m_2 n_3 - m_3 n_2} x + \frac{p_3 m_2 - p_2 m_3}{m_2 n_3 - m_3 n_2} \tag{1.27}$$

$$\text{i.e., } z \equiv a_2 x + b_2 \tag{1.28}$$

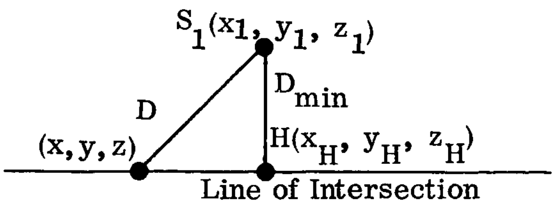
In symmetric form, the equation of the line of intersection is

$$\frac{x}{1} = \frac{y - b_1}{a_1} = \frac{z - b_2}{a_2} \tag{1.29}$$

Direction cosines of the line are

$$\frac{1}{(1 + a_1^2 + a_2^2)^{1/2}}, \quad \frac{a_1}{(1 + a_1^2 + a_2^2)^{1/2}}, \quad \frac{a_2}{(1 + a_1^2 + a_2^2)^{1/2}}. \tag{1.30}$$

Points on intersection line at distance r_1 from (x_1, y_1, z_1)



Eq. of line:

$$y = a_1 x + b_1$$

$$z = a_2 x + b_2$$

Figure 1.4. CLOSEST APPROACH GEOMETRY

1.) Closest Approach Point (figure 1.4)

First find coordinates (x_H, y_H, z_H) of point H, which is point on line closest to S_1

$$D^2 = (x - x_1)^2 + (y - y_1)^2 + (z - z_1)^2$$

$$= (x - x_1)^2 + (a_1 x + b_1 - y_1)^2 + (a_2 x + b_2 - z_1)^2$$

D is minimum when D^2 is minimum when

$$\frac{dD^2}{dx} = 2(x-x_1) + 2a_1(a_1 x + b_1 - y_1) + 2a_2(a_2 x + b_2 - z_1) = 0.$$

Solving for $x\,(= x_H)$,

$$\left.\begin{aligned} x_H &= \frac{x_1 + a_1(y_1 - b_1) + a_2(z_1 - b_2)}{1 + a_1^2 + a_2^2} \\ \text{then from (1.26) and (1.28),} \quad y_H &= a_1 x_H + b_1 \\ z_H &= a_2 x_H + b_2 \quad , \end{aligned}\right\} \quad (1.31)$$

and

$$D_{min} = \left[(x_H - x_1)^2 + (y_H - y_1)^2 + (z_H - z_1)^2 \right]^{1/2} \quad (1.32)$$

2.) Possible Vehicle Position Points (figure 1.5)

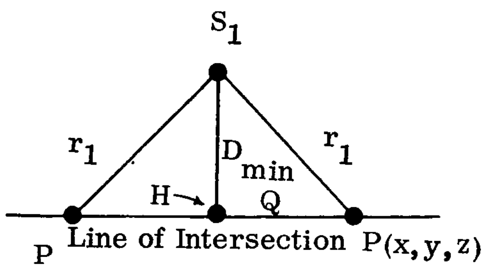


Figure 1.5. POSSIBLE VEHICLE POSITIONS

The two points P on the line of intersection, which are at a distance r_1 from S_1, can be obtained from the coordinates of H (eq. 1.31), the length $Q = \left(r_1^2 - D_{min}^2\right)^{1/2}$, and the direction cosines of the line of intersection (eq. 1.30):

$$\left.\begin{aligned} x &= x_H \pm \frac{Q}{(1+a_1^2+a_2^2)^{1/2}} \\ y &= y_H \pm \frac{Qa_1}{(1+a_1^2+a_2^2)^{1/2}} \\ z &= z_H \pm \frac{Qa_2}{(1+a_1^2+a_2^2)^{1/2}} \end{aligned}\right\} \quad (1.33)$$

Finally, eliminate ambiguous solution by rejecting that P for which $x^2 + y^2 + z^2 < R_E^2$, R_E = radius earth. This is a satisfactory test for AROD orbital altitudes of interest.

Summary

The computation requirements for the above sequence may be simplified by assuming that for known station sites, the separation distances S_1S_2 and S_1S_3 are pre-computable, and further that the points $K_2 = (x_{K_2}, y_{K_2}, z_{K_2})$ between stations 1 and 2, and $K_3 = (x_{K_3}, y_{K_3}, z_{K_3})$ between stations 1 and 3 can also be predetermined.

Thus the program inputs are:

Stations	Separations	Chord Points	Ranges	Radius Earth
x_1, y_1, z_1	S_1S_2	$x_{K_2}, y_{K_2}, z_{K_2}$	r_1	R_E
x_2, y_2, z_2	S_1S_3	$x_{K_3}, y_{K_3}, z_{K_3}$	r_2	
x_3, y_3, z_3			r_3	

Required Computations:

$$L_2 \equiv \frac{S_1C_2}{S_1S_2} = \frac{r_1^2 + (S_1S_2)^2 - r_2^2}{2(S_1S_2)^2}$$

$$x_{C_2} = x_1 + L_2(x_2 - x_1)$$

$$y_{C_2} = y_1 + L_2(y_2 - y_1)$$

$$z_{C_2} = z_1 + L_2(z_2 - z_1)$$

$$p_2 = \left[(x_{C_2} - x_{K_2})^2 + (y_{C_2} - y_{K_2})^2 + (z_{C_2} - z_{K_2})^2 \right]^{1/2}$$

$$\ell_2 = (x_{C_2} - x_{K_2})/p_2$$

$$m_2 = (y_{C_2} - y_{K_2})/p_2$$

$$n_2 = (z_{C_2} - z_{K_2})/p_2$$

Repeat above sequence with subscripts "2" replaced by "3" and obtain ℓ_3, m_3, n_3.

$$M = m_2 n_3 - m_3 n_2$$

$$a_1 = \frac{1}{M}(\ell_3 n_2 - \ell_2 n_3)$$

$$b_1 = \frac{1}{M}(p_2 n_3 - p_3 n_2)$$

$$a_2 = \frac{1}{M}(\ell_2 m_3 - \ell_3 m_2)$$

$$b_2 = \frac{1}{M}(p_3 m_2 - p_2 m_3)$$

$$N = (1 + a_1^2 + a_2^2)^{1/2}$$

$$x_H = \frac{1}{N^2}\left[x_1 + a_1(y_1 - b_1) + a_2(z_1 - b_2)\right]$$

$$y_H = a_1 x_H + b_1$$

$$z_H = a_2 x_H + b_2$$

$$D_{min}^2 = (x_H - x_1)^2 + (y_H - y_1)^2 + (z_H - z_1)^2$$

$$Q = (r_1^2 - D_{min}^2)^{1/2}$$

Vehicle Position:

$$x = x_H \pm \frac{Q}{N}$$

$$y = y_H \pm \frac{Qa_1}{N}$$

$$z = z_H \pm \frac{Qa_2}{N}$$

Test: Reject the triple (x, y, z) for which $x^2 + y^2 + z^2 < R_E^2$.

1.1.1.3 Velocity Determination

The velocity navigation equations using the solution to the position equations as a known input are a set of three linear equations in three unknowns and can be solved easily by the method of determinants. The velocity navigation equations may be written as:

$$(x - x_i)(\dot{x} - \dot{x}_i) + (y - y_i)(\dot{y} - \dot{y}_i) + (z - z_i)(\dot{z} - \dot{z}_i) = r_i \dot{r}_i \qquad (1.34)$$

$$i = 1, 2, 3$$

where x, y, z are obtained from position equations and $r, \dot{r}$ are measured quantities. The station position and velocity coordinates are predictable functions of time. For example, in the inertial geocentric system:

$$\left.\begin{aligned} x_i &= R_i \cos\psi_i \cos\lambda_i(t) \\ y_i &= R_i \cos\psi_i \sin\lambda_i(t) \\ z_i &= R_i \sin\psi_i = \text{constant} \end{aligned}\right\} ; \qquad i=1,2,3 \qquad (1.34a)$$

$$\left.\begin{aligned}
&\lambda_i(t) = \lambda_{i_o} + \Omega_E(t - t_o) \\
&\dot{x}_i = -\Omega_E R_i \cos\psi_i \sin\lambda_i(t) \\
&\dot{y}_i = \Omega_E R_i \cos\psi_i \cos\lambda_i(t) \\
&\dot{z}_i = 0
\end{aligned}\right\} \qquad (1.34b)$$

where R_i, ψ_i are fixed quantities specifying station range and latitude angle respectively.

λ_{i_o} is the initial $(t = t_o)$ value of station longitude angle

Ω_E is the known value of earth rotation rate.

Returning to eq. 1.34 and expanding for three stations,

$$(x - x_1)(\dot{x} - \dot{x}_1) + (y - y_1)(\dot{y} - \dot{y}_1) + (z - z_1)(\dot{z}) = r_1\dot{r}_1 \qquad (1.35)$$

$$(x - x_2)(\dot{x} - \dot{x}_2) + (y - y_2)(\dot{y} - \dot{y}_2) + (z - z_2)(\dot{z}) = r_2\dot{r}_2 \qquad (1.36)$$

$$(x - x_3)(\dot{x} - \dot{x}_3) + (y - y_3)(\dot{y} - \dot{y}_3) + (z - z_3)(\dot{z}) = r_3\dot{r}_3 \qquad (1.37)$$

where

x, y, z solved from position navigation equations

$\dot{x}, \dot{y}, \dot{z}$ to be determined

Rewrite eq. 1.35, eq. 1.36, eq. 1.37:

$$\dot{x}(x - x_1) + \dot{y}(y - y_1) + \dot{z}(z - z_1) + \dot{x}_1(x_1 - x) + \dot{y}_1(y_1 - y) - r_i\dot{r}_1 = 0 \qquad (1.38)$$

$$\dot{x}(x - x_2) + \dot{y}(y - y_2) + \dot{z}(z - z_2) + \dot{x}_2(x_2 - x) + \dot{y}_2(y_2 - y) - r_2\dot{r}_2 = 0 \qquad (1.39)$$

$$\dot{x}(x - x_3) + \dot{y}(y - y_3) + \dot{z}(z - z_3) + \dot{x}_3(x_3 - x) + \dot{y}_3(y_3 - y) - r_3\dot{r}_3 = 0 \qquad (1.40)$$

Thus,

eq 1.38 $$K_{12}\dot{x} + K_{13}\dot{y} + K_{14}\dot{z} = K_{15}$$

eq 1.39 $$K_{16}\dot{x} + K_{17}\dot{y} + K_{18}\dot{z} = K_{19}$$

eq 140 $$K_{20}\dot{x} + K_{21}\dot{y} + K_{22}\dot{z} = K_{23}$$

and,

$$\dot{x} = \frac{\begin{vmatrix} K_{15} & K_{13} & K_{14} \\ K_{19} & K_{17} & K_{18} \\ K_{23} & K_{21} & K_{22} \end{vmatrix}}{\begin{vmatrix} K_{12} & K_{13} & K_{14} \\ K_{16} & K_{17} & K_{18} \\ K_{20} & K_{21} & K_{22} \end{vmatrix}} = \frac{K_{15}(K_{17}K_{22}-K_{18}K_{21}) + K_{13}(K_{18}K_{23}-K_{19}K_{22}) + K_{14}(K_{19}K_{21}-K_{17}K_{23})}{K_{12}(K_{17}K_{22}-K_{18}K_{21}) + K_{13}(K_{18}K_{20}-K_{16}K_{22}) + K_{14}(K_{16}K_{21}-K_{17}K_{20})}$$

$$\dot{y} = \frac{\begin{vmatrix} K_{12} & K_{15} & K_{14} \\ K_{16} & K_{19} & K_{18} \\ K_{20} & K_{23} & K_{22} \end{vmatrix}}{\overline{D}} = \frac{K_{12}(K_{19}K_{22}-K_{18}K_{23}) + K_{15}(K_{18}K_{20}-K_{16}K_{22}) + K_{14}(K_{16}K_{23}-K_{19}K_{20})}{\overline{D}}$$

$$\dot{z} = \frac{\begin{vmatrix} K_{12} & K_{13} & K_{15} \\ K_{16} & K_{17} & K_{19} \\ K_{20} & K_{21} & K_{23} \end{vmatrix}}{\overline{D}} = \frac{K_{12}(K_{17}K_{23}-K_{19}K_{21}) + K_{13}(K_{19}K_{20}-K_{16}K_{23}) + K_{15}(K_{16}K_{21}-K_{17}K_{20})}{\overline{D}}$$

where

$K_{12} = x - x_1$ $\quad K_{13} = y - y_1$ $\quad K_{14} = z - z_1$

$K_{16} = x - x_2$ $\quad K_{17} = y - y_2$ $\quad K_{18} = z - z_2$

$K_{20} = x - x_3$ $\quad K_{21} = y - y_3$ $\quad K_{22} = z - z_3$

$$K_{15} = r_1\dot{r}_1 + \dot{x}_1(x - x_1) + \dot{y}_1(y - y_1)$$

$$K_{19} = r_2\dot{r}_2 + \dot{x}_2(x - x_2) + \dot{y}_2(y - y_2)$$

$$K_{23} = r_3\dot{r}_3 + \dot{x}_3(x - x_3) + \dot{y}_3(y - y_3)$$

$$\bar{D} = K_{12}(K_{17}K_{22} - K_{18}K_{21}) + K_{13}(K_{18}K_{20} - K_{16}K_{22}) + K_{14}(K_{16}K_{21} - K_{17}K_{20})$$

1.1.1.4 Math Flow Diagrams

The equations previously discussed for determining spacecraft position (by three methods) and velocity will now be presented in the form of flow diagrams for the sequence of mathematical operations, (Figures 1.6, 1.7, 1.8, and 1.9).

Inputs

$t_o, t, \lambda_{10}, \lambda_{20}, \lambda_{30}, R_E$

$\Omega_E, \psi_1, \psi_2, \psi_3$

$R_1, R_2, R_3, r_1, r_2, r_3$

$z_1, z_2, z_3, \dot{r}_1, \dot{r}_2, \dot{r}_3$

Update Station Coord's to Time t

$$\lambda_1(t) = \lambda_{10} + (\Omega_E)(t - t_o)$$
$$\lambda_2(t) = \lambda_{20} + (\Omega_E)(t - t_o)$$
$$\lambda_3(t) = \lambda_{30} + (\Omega_E)(t - t_o)$$
$$x_1 = R_1 [\cos \psi_1][\cos \lambda_1(t)]$$
$$y_1 = R_1 [\cos \psi_1][\sin \lambda_1(t)]$$
$$x_2 = R_2 [\cos \psi_2][\cos \lambda_2(t)]$$
$$y_2 = R_2 [\cos \psi_2][\sin \lambda_2(t)]$$
$$x_3 = R_3 [\cos \psi_3][\cos \lambda_3(t)]$$
$$y_3 = R_3 [\cos \psi_3][\sin \lambda_3(t)]$$

$$a = (y_1 - y_2)/(x_2 - x_1)$$
$$b = (z_1 - z_2)/(x_2 - x_1)$$
$$K_1 = x_1^2 + y_1^2 + z_1^2 - r_1^2$$
$$K_2 = x_2^2 + y_2^2 + z_2^2 - r_2^2$$
$$K_3 = x_3^2 + y_3^2 + z_3^2 - r_3^2$$
$$c = (K_2 - K_1)/2(x_2 - x_1)$$

$$K_4 = 2(-ax_1 - y_1 + ax_3 + y_3)$$
$$K_5 = 2(-bx_1 - z_1 + bx_3 + z_3)$$
$$K_6 = K_3 - K_1 + 2c(x_1 - x_3)$$

$$K_7 = -K_5/K_4$$
$$K_8 = K_6/K_4$$

$$K_9 = K_7^2(a^2 + 1) + b^2 + 1 + 2K_7ab$$
$$K_{10} = 2[K_7K_8(a^2 + 1) + K_8ab + K_7(ac - ax_2 - y_2) + (bc - bx_2 - z_2)]$$
$$K_{11} = K_8^2(a^2 + 1) + 2K_8(ac - ax_2 - y_2) + K_2 + c^2 - 2cx_2$$

$$z' = \frac{-K_{10} + \sqrt{(K_{10})^2 - 4K_9K_{11}}}{2K_9}$$
$$y' = K_7z' + K_8$$
$$x' = ay' + bz' + c$$

$$\epsilon = x'^2 + y'^2 + z'^2 - R_E^2$$

ϵ

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$$z'' = \frac{-K_{10} - \sqrt{(K_{10})^2 - 4K_9K_{11}}}{2K_9}$$
$$y'' = K_7z'' + K_8$$
$$x'' = ay'' + bz'' + c$$

To Velocity Computation

Figure 1.6. AROD POSITION COMPUTATION DIRECT SOLUTION

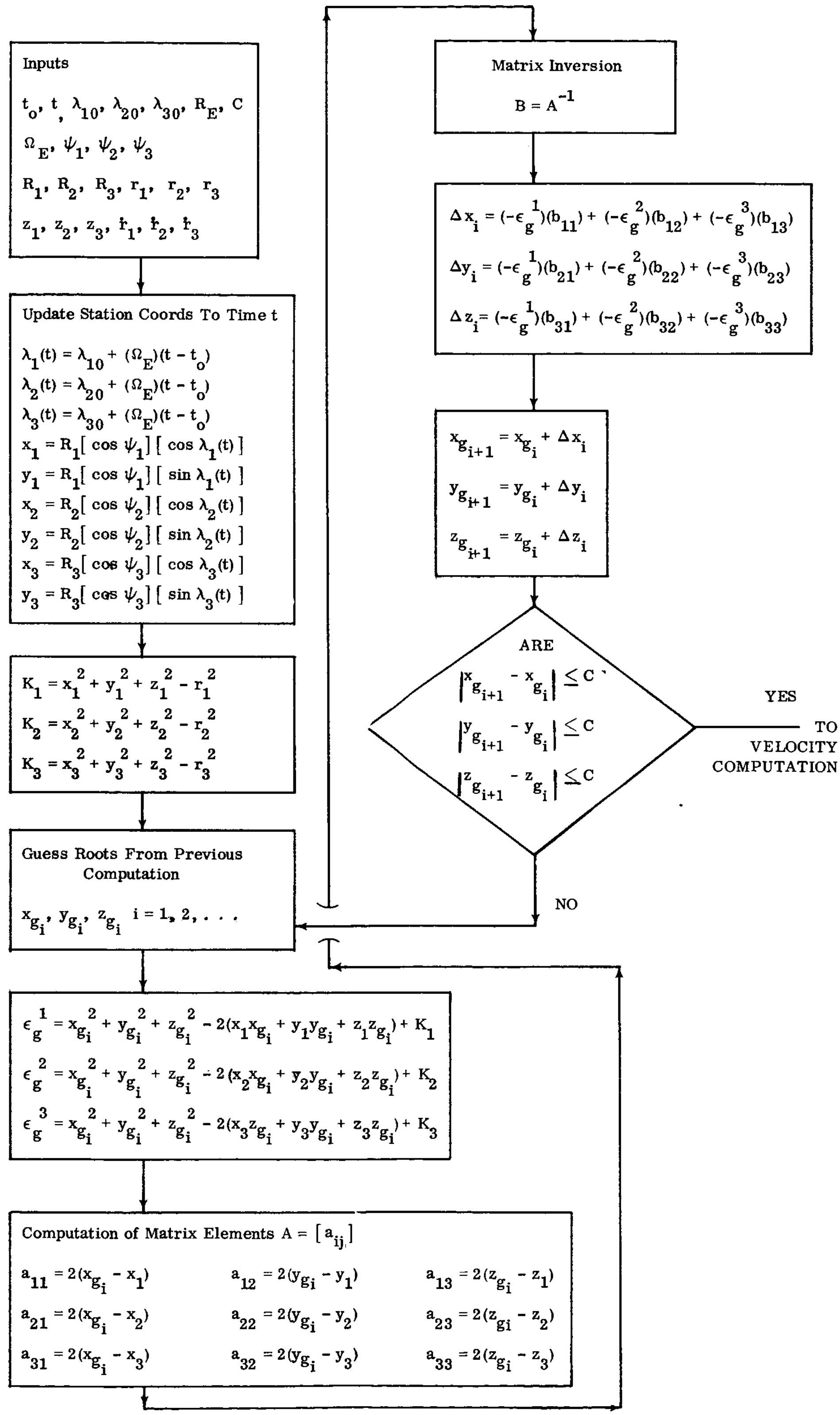

Figure 1.7. AROD POSITION COMPUTATION METHOD OF DIFFERENTIAL CORRECTION

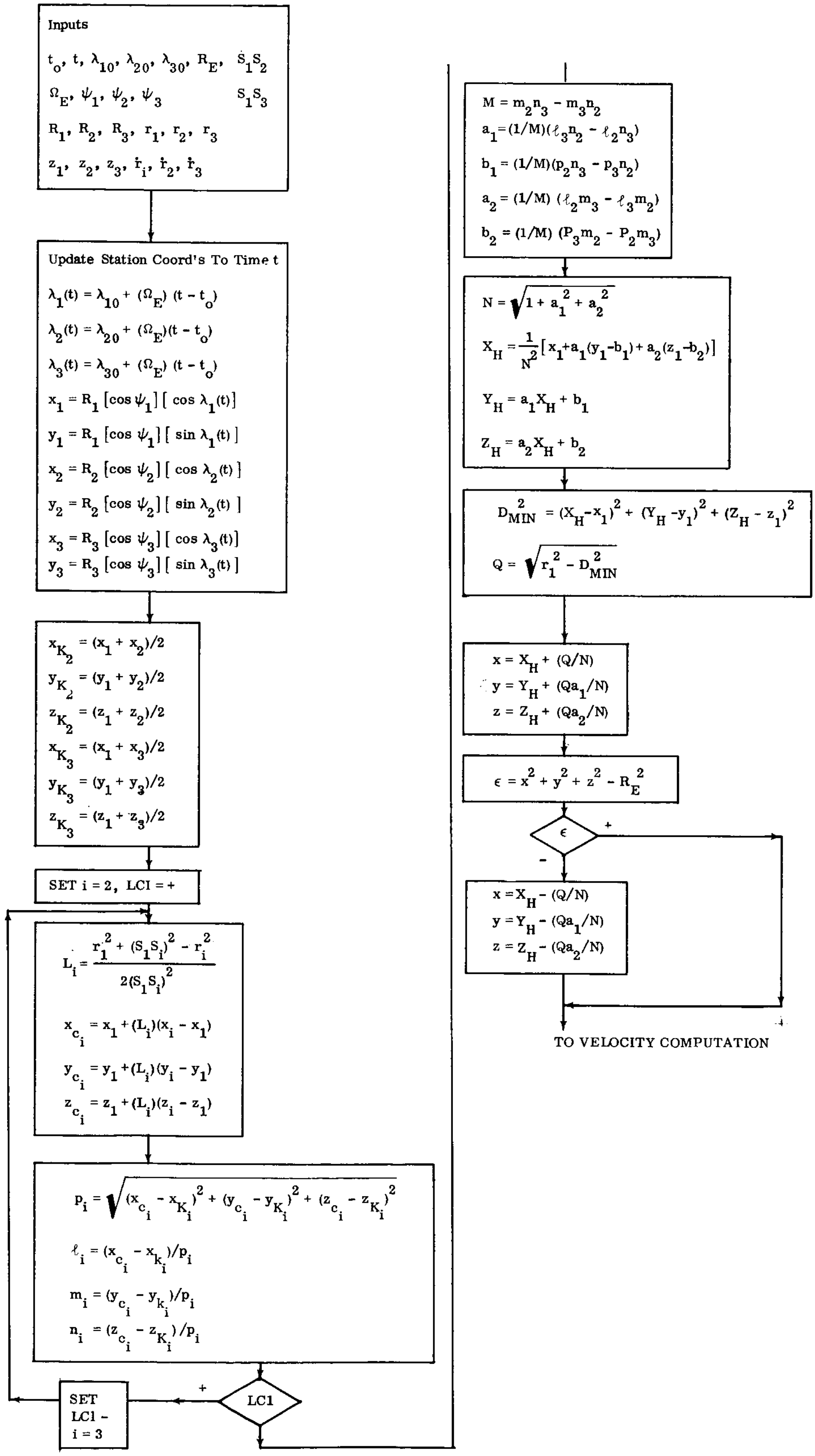

Figure 1.8. AROD POSITION COMPUTATION ANALYTIC GEOMETRY METHOD

Inputs

$r_1, r_2, r_3 \qquad \lambda_1(t) \qquad \lambda_2(t) \qquad \lambda_3(t)$

$\dot{r}_1, \dot{r}_2, \dot{r}_3$

x, y, z from position computation

Update Station Velocity Coordinates

$$\dot{x}_1 = -\Omega_E R_1 [\cos \psi_1][\sin \lambda_1(t)]$$
$$\dot{y}_1 = \Omega_E R_1 [\cos \psi_1][\cos \lambda_1(t)]$$
$$\dot{x}_2 = -\Omega_E R_2 [\cos \psi_2][\sin \lambda_2(t)]$$
$$\dot{y}_2 = \Omega_E R_2 [\cos \psi_2][\cos \lambda_2(t)]$$
$$\dot{x}_3 = -\Omega_E R_3 [\cos \psi_3][\sin \lambda_3(t)]$$
$$\dot{y}_3 = \Omega_E R_3 [\cos \psi_3][\cos \lambda_3(t)]$$

$$K_{12} = x - x_1 \qquad K_{16} = x - x_2 \qquad K_{20} = x - x_3$$
$$K_{13} = y - y_1 \qquad K_{17} = y - y_2 \qquad K_{21} = y - y_3$$
$$K_{14} = z - z_1 \qquad K_{18} = z - z_2 \qquad K_{22} = z - z_3$$

$$K_{15} = \dot{r}_1 \dot{r}_1 + (x_1)(x - x_1) + (\dot{y}_1)(y - y_1)$$
$$K_{19} = r_2 \dot{r}_2 + (\dot{x}_2)(x - x_2) + (\dot{y}_2)(y - y_2)$$
$$K_{23} = r_3 \dot{r}_3 + (\dot{x}_3)(x - x_3) + (\dot{y}_3)(y - y_3)$$

$$\bar{D} = K_{12}(K_{17}K_{22} - K_{18}K_{21}) + K_{13}(K_{18}K_{20} - K_{16}K_{22}) + K_{14}(K_{16}K_{21} - K_{17}K_{20})$$

$$\dot{x} = [K_{15}(K_{17}K_{22} - K_{18}K_{21}) + K_{13}(K_{18}K_{23} - K_{19}K_{22}) + K_{14}(K_{19}K_{21} - K_{17}K_{23})]/\bar{D}$$
$$\dot{y} = [K_{12}(K_{19}K_{22} - K_{18}K_{23}) + K_{15}(K_{18}K_{20} - K_{16}K_{22}) + K_{14}(K_{16}K_{23} - K_{19}K_{20})]/\bar{D}$$
$$\dot{z} = [K_{12}(K_{17}K_{23} - K_{19}K_{21}) + K_{13}(K_{19}K_{20} - K_{16}K_{23}) + K_{15}(K_{16}K_{21} - K_{17}K_{20})]/\bar{D}$$

Figure 1.9. AROD VELOCITY COMPUTATIONS

1.1.2 Auxiliary Computations

The auxiliary computations consist primarily of the transformation of "raw" AROD data to range and range rate data; corrections to the data for various effects; reasonableness tests to determine the validity of the data; the determination of which transponders will be turned on or off; and the overall logical control of the data flow in the computer prior to the final transfer to the guidance and control routines. The work to date has concentrated on the transformation from the raw AROD data to range and range rate quantities, and corrections to the data. Paragraphs 1.1.2.1 and 1.1.2.2 discuss the range and range rate computations respectively.

Figure 1.10 presents a general block diagram of the functions that may be required (depending upon the find implementation) in the range and range rate calculations. In this figure, the subscript, i, refers to a particular transponder. For instance N_2 would be the cycle count associated with transponder number 2. A glossary of the symbols used in Figure 1.10 will be given here since they are used elsewhere.

t_c - start time of all range rate measurements

N_i - cycle count for i^{th} transponder

t_o - start time of range measurements*

t_i - termination time for i^{th} transponder range measurement*

T_i - frequency translation used by i^{th} transponder

f_t - transmitted frequency

n - index of refraction

t_d - time associated with all range rate measurements

h - altitude

c - velocity of propagation in a vacuum

* For the purposes of this analysis, it is immaterial whether the range measurements start simultaneously or terminate simultaneously.

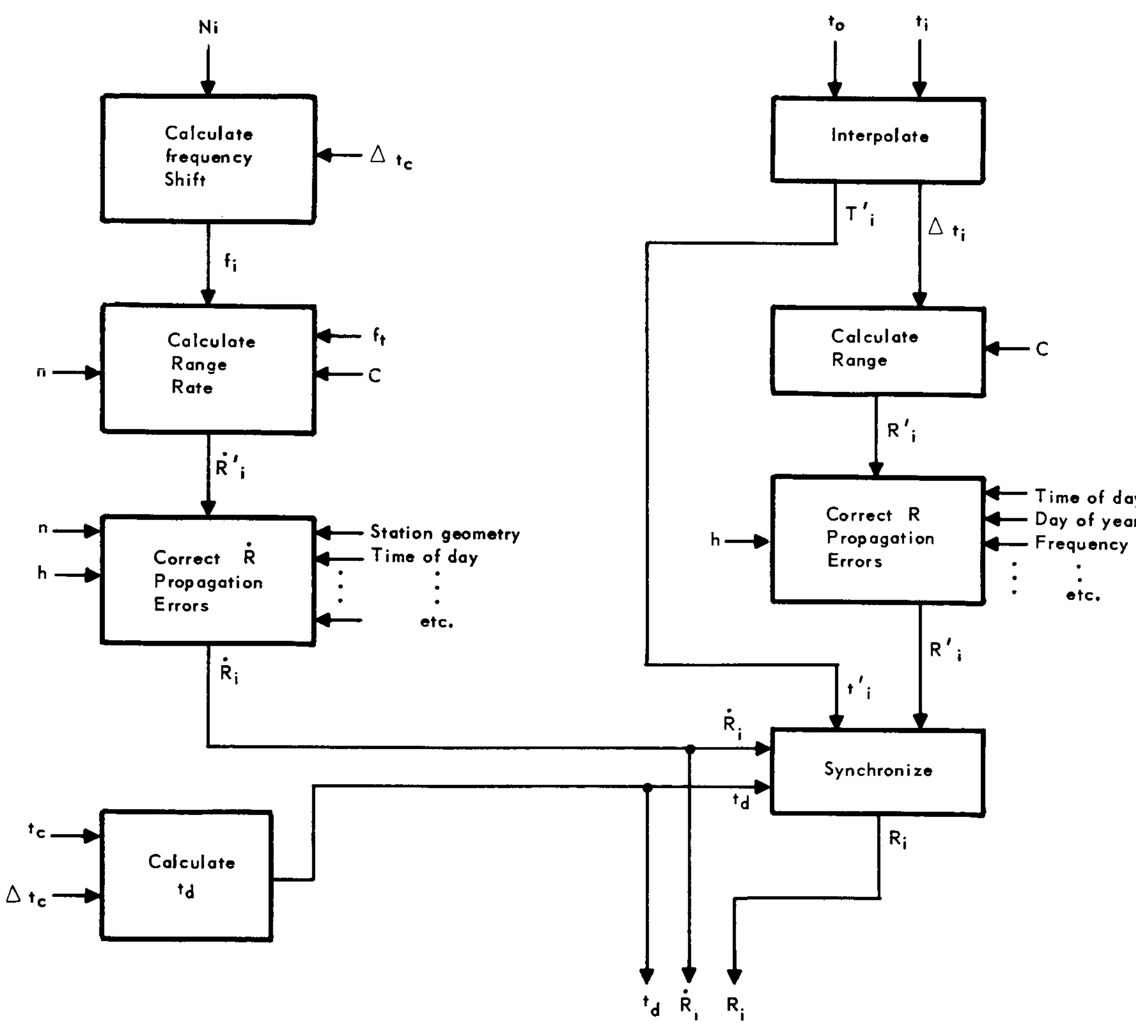

Figure 1.10. GENERALIZED FLOW OF RANGE AND RANGE RATE COMPUTATIONS

1.1.2.1 Range Calculations

The range calculation problem consists of not only the range computation problem but also a time translation problem. For convenience, the range computation problem will be divided into two steps. The first of these is the transformation from the basic AROD data to an approximate range by a simple multiplication, using the velocity of propagation for a vacuum, c. This must then be followed by a propagation correction compensating for the fact that the velocity of propagation is indeed not that for a perfect vacuum.

Once accurate range measurements have been obtained, it is necessary to associate them with an appropriate time point. This time translation problem is by necessity also a two step operation. The first step (i. e., interpolation) must compensate for the error introduced in the range measurements due to the movement of the vehicle during the measurement interval. A second step (i. e., synchronization) may also be necessary to re-align the several range measurements to a common time point.

The correction for propagation errors is the most complicated problem; it must take into account the integrated effect of the variation in the index of refraction as the radiated energy passes through the atmosphere. The difficulty arises in trying to assign quantitative values for n. Once this has been done, it will be a straight forward problem to implement the correction using either a pre-stored table or an analytical expression. Tentative results indicate that the propagation correction as a function of range to the transponder may be a family of straight lines whose slopes are determined by the altitude or elevation angle. If this is indeed the case, the analytical expression will be extremely simple, requiring the storage of only constants defining the slopes.

The interpolation and synchronization problems are somewhat related. Since the vehicle can move a considerable distance during the range measurement interval, it is necessary to interpolate the data to ensure that this range measurement is associated with the correct point in space.

An analysis of the interpolation problem using a Taylor series expansion indicates that the acceleration effects are insignificant. Therefore, over the small range measurement time interval, the vehicle velocity can be assumed to be constant. This simplifies the analysis since the time to associate with the range measurement will just be the mid-point of the time interval. Preliminary calculations indicate that associating the average range with this time point results in an error that never exceeds 10^{-3} meters (which is negligible).

Once the individual range measurements with their associated times have been computed, it may be necessary to synchronize them to a common time. This correction can also be made using the Taylor Series expansion. Since the contribution from the r term is insignificant, only the first two terms of the expansion are required to synchronize the data.

1.1.2.2 Range Rate Calculations

As shown in Figure 1.9, there are several functions that must be performed to obtain accurate range rate data. An approximate range rate is computed by first calculating the doppler frequency from the cycle count data and then solving the doppler equation. An accurate range rate measurement is then obtained by making a propagation correction. Since the cycle counting interval is of the order of 0.25 sec. it is also necessary to determine the time point for which this average range rate applies.

The propagation corrections on $\dot{r}$ must take into account the integrated effect of the index of refraction, n, through the atmosphere. In addition, knowledge of the instantaneous value of the index of refraction at the spacecraft could further reduce the propagation errors. The integrated effect causes an error due to the angle between the curved path and the line-of-sight path at the vehicle, while the instantaneous n determines the actual velocity of propagation at the vehicle. An investigation of the range of values of the index of refraction indicates that it may be possible to store values of n as a function of altitude or elapsed time for a specific mission.

The major problem remaining in the range rate computations is the correction for the integrated effect of the index of refraction. The problem lies in the lack of adequate data describing the atmosphere as a function of geography, season, sun activity, etc. From these data a range rate correction and a rms error after correction must be computed. This range rate correction will either be entered into the computer as stored data and accessed by a table look-up routine or will be approximated by an equation that can be solved when a correction is needed. The trade-off between computation time and storage space as well as the feasibility of using an approximation equation will be examined during the next quarter.

Since the range rate measurement is taken over an interval of approximately 0.25 sec. it is necessary to assign a time, to this average range rate. In a similar manner to the range measurement, an analysis by Taylor Series expansion for range rate indicates that the $\dddot{r}$ term is insignificant. Therefore, the best time to associate with the range rate measurement is the mid-point of the measurement interval.

1.1.3 COMPUTER TIME AND STORAGE ESTIMATES

Preliminary estimates of the computer time and storage requirements for the basic and auxiliary computations have been made. The computer used in these estimates is the Saturn V Digital Computer described in Doc. No. TN587-38 (IBM Owego).

Since the basic AROD computations are the major contributors to the total time estimate, they will be discussed in some detail, using the direct solution (for the position computation) presented in section 1.1.1.2.1. Exclusive of sine, cosine, and square root operations the computation procedure illustrated in the math flow diagrams requires 456 stored instructions and 816 instruction executions. The sine-cosine routine will require approximately 60 storage locations and 70 instruction executions. Each entry will calculate both the sine and cosine of the value. The square root subroutine will be assumed to require 30 storage locations and 75 instruction executions. This assumes 3 iterations to achieve the desired accuracy.

It must also be recognized that the solution of these equations must be accomplished on a fixed point computer. This will involve considerable manipulation of the data (scaling). The estimates have, therefore, been corrected by a factor that has been found reasonable, based upon past experience.

The instruction storage requirements are summarized below:

Main program	456
Sin-cos and square root subroutines	90
15% for scaling	82
Total 13 list words	628

Total 26 list words	314
Data storage requirements	80
Total 26 list storage	394 words

As shown in Figure 1.6, a decision must be made to either use or bypass the last block. The left hand column in the time summary given below assumes this block has been bypassed. The right hand column includes the last block.

Time Summary:

Main program	761	816
Sine-cosine and square root subroutines	285	285
20% for scaling	209	220
Total instruction executions at 84μsec per instruction	1255	1321
Total time required	0.105 sec.	0.111 sec.

The estimates of the time requirements for the auxiliary computations will depend to a great extent on the type of propagation error corrections used as well as the method of station selection. Since the analysis of these two problems has not been completed, specific numbers cannot be stated. However, a conservative estimate of the time required can reasonably be assumed to be 0.1 seconds. Using these estimates, the total computer time required for all AROD computations is estimated to be 0.2 seconds ±0.1 seconds.

It is anticipated that a final estimate for the total computer storage and time requirements will be obtained during the next quarter.

1.2 LAUNCH TRAJECTORY ERROR ANALYSIS

A preliminary analysis of the Geometrical Dilution of Precision (GDOP) resulting from the use of AROD as an AMR launch-guidance back-up system was conducted by means of the AROD Error Evaluation Computer Program.* This program, which is discussed in detail in Appendix A of the AROD Design Feasibility Report (IBM #TR023-022), computes the error amplifying effects of vehicle-to-station geometry in terms of position and velocity covariance error matrices. The elements of these matrices, in turn, are used to compute the magnitudes and spatial orientations of error ellipsoid semi-axes corresponding to the diagonalized forms of the position and velocity covariance matrices. In this way a description of the error volumes within which vehicle position and velocity can be expected to lie with specified probability is obtained. These data (and additional related measures of net system accuracy) are generated at specified increments of time within the observation region defined by the instantaneous vehicle position and three AROD transponder locations.

1.2.1 Description of Computer Runs

A "typical" Saturn launch trajectory, as supplied by NASA Huntsville (Reel No. 6792, Log No. B7, Unit No. 24, 3 Sept. 63), was utilized for the launch trajectory GDOP analysis runs. These trajectory data are expressed in terms of a Cape Canaveral topocentric-rectangular reference frame.

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* The orbital computation portion of the AROD Error Evaluation Computer Program was modified to accomodate NASA launch trajectory data against which the performance of AROD is to be measured.

By expressing AROD transponder location inputs in the trajectory reference frame, it is possible to output the computer program data in this reference frame also. Thus, all position-velocity data herein described are in terms of a Cape Canaveral topocentric-rectangular triad ($\bar{x}_s$, $\bar{y}_s$, $\bar{z}_s$) defined as follows:

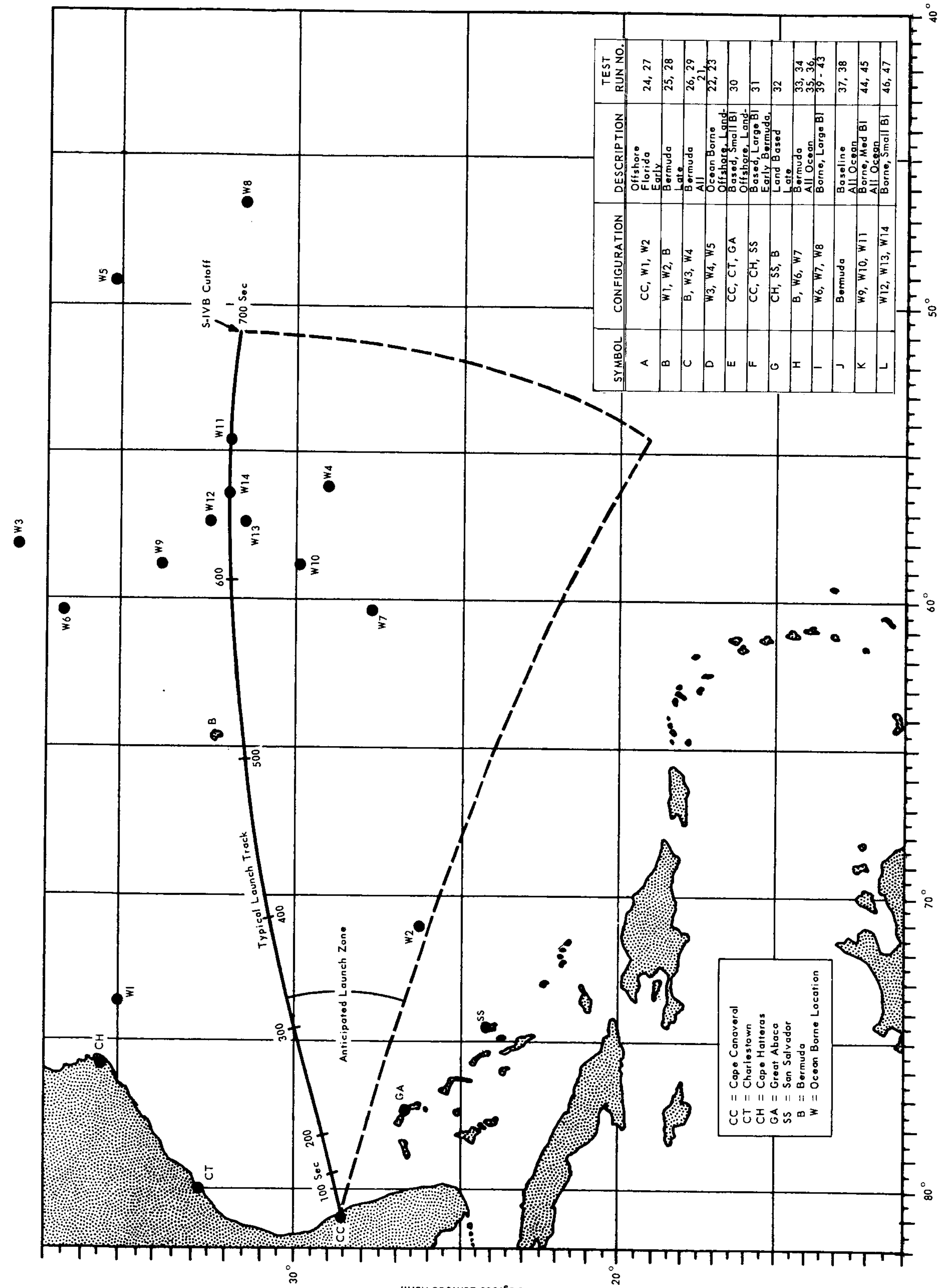
$\bar{y}_s$ is in the direction of the local vertical, positive up

$\bar{x}_s$ is in the direction of the launch azimuth angle, positive forward (downrange)

$\bar{z}_s$ is directed to form a right-handed set

The x_s, y_s, z_s data are thus conveniently described as down-range, altitude, and cross-range data, respectively. In accordance with stipulated launch trajectory characteristics, a launch azimuth angle of 72° is assumed. Latitude and longitude of Cape Canaveral are taken as 28.5°N and 80.5°W, respectively; a spherical earth of radius 6.371×10^6 M is assumed for these first test runs.

Several AROD transponder (station) configurations, designed to permit ready analysis of GDOP effects throughout the course of the 706 second launch trajectory, are incorporated in these tests. The assumed AROD transponder locations (both land-based and oceanborne) are shown in Figure 1.11. Included in Figure 1.11 is a table detailing the manner by which these various locations were combined to provide a total of twelve transponder configurations (designated A through L) for the test runs. Figure 1.11 also shows the anticipated launch zone for the Saturn vehicle and an earth-track of a typical Saturn launch trajectory. Note that some of the transponder configurations (e.g., A, E, F) allow early monitoring of AMR launch trajectories, while others (B, G, J) allow "midcourse" monitoring, and still others (C, D, H, I, K, L) allow "terminal" (insertion) monitoring. It should also be noted that some of the assumed configurations are all land-based (E, F, G, J), some are all



SYMBOL	CONFIGURATION	DESCRIPTION	TEST RUN NO.
A	CC, W1, W2	Offshore Florida Early	24, 27
B	W1, W2, B	Bermuda Late	25, 28
C	B, W3, W4	Bermuda All	26, 29
D	W3, W4, W5	Ocean Borne	21, 22, 23
E	CC, CT, GA	Offshore, Land-Based, Small Bl	30
F	CC, CH, SS	Offshore, Land-Based, Large Bl	31
G	CH, SS, B	Early Bermuda, Land Based	32
H	B, W6, W7	Late Bermuda	33, 34 35, 36,
I	W6, W7, W8	All Ocean Borne, Large Bl	39 - 43
J	Bermuda	Baseline	37, 38
K	W9, W10, W11	All Ocean Borne, Med Bl	44, 45
L	W12, W13, W14	All Ocean Borne, Small Bl	46, 47

Figure 1.11. AMR-AROD TRANSPONDER CONFIGURATION

oceanborne (D, I, K, L), and some are combination land-based and oceanborne (A, C, H). To assess the GDOP effects of configuration baseline distance, "large", "medium", and "short" baselines characterize several of the assumed configurations. Station location program inputs are modified slightly over those shown in Figure 1.11 to approximate the effects of earth rotation over the observation interval associated with each configuration.

Two combinations of AROD range measurement accuracy (as specified by range RMS error, σ_r) and range rate measurement accuracy(($\sigma_{\dot{r}}$) are assumed for the test runs. The values chosen for these combinations (σ_r = 3M, $\sigma_{\dot{r}}$ = 0.05 M/sec and σ_r = 10M, $\sigma_{\dot{r}}$ = 0.15 M/sec) are considered reasonable in view of the AROD design philosophy and conclusions drawn in the AROD Design Feasibility Report. All three range RMS errors are assumed equal and constant throughout a given test run; the corresponding three range rate RMS errors are likewise assumed equal and constant.

To obtain first estimates of the GDOP effects of transponder location uncertainties, several combinations of station coordinate uncertainties are employed. In general, all land-based station coordinate errors and all oceanborne altitude errors are assumed to be accurately known while oceanborne latitude and longitude errors are assumed to be less well known.* Actual numerical values assumed for station coordinate errors

*In view of the relatively short geocentric angle subtended by the farthest down-range station location, the topocentric y_s coordinate error is taken as a direct measure of station altitude error. For the same reason, the topocentric x_s and z_s coordinate errors are taken as direct measures of station longitude and latitude errors, respectively. For notational convenience, the station altitude error is symbolized by σ_h and station longitude and latitude errors by σ_ℓ.

are tabulated, along with corresponding test run numbers, in Table 1.1. Station coordinate bias errors are assumed only for the "Bermuda Baseline" test runs (Runs 37, 38), for which longitudinal bias errors of 15M are taken for each transponder location.

For each test run, all transponders are assumed to be elevation-angle-limited to 5° above the local horizon. Table 1.1 summarizes the important characteristics of each test run.

1.2.2 Discussion of Computer Results

The results obtained for the computer runs listed in Table 1.1 are summarized in the computer print-out data of paragraph 1.2.4; in addition, some of the data are presented graphically in Figures 1.12 through 1.16. Note that in each figure the maximum axes of the position and velocity covariance error ellipsoids are used as summary measures of system accuracy; for ease of discussion, these quantities are hereafter referred to as the AROD position and velocity system errors. In most of the figures, AROD system errors are plotted adjacently as functions of time from lift-off in order to permit simultaneous evaluation. The first and last points indicated on each time plot represent the first and last launch trajectory points lying within the elevation-angle-limited observation region; a direct measure of the total observation interval T associated with each configuration is thus provided by the time plots.

Figure 1.12 plots the performance capability (as measured by error ellipsoid maximum axes) of several down-range AROD configurations adjacent to a time-history plot of a typical AMR Saturn launch trajectory. This is a summary plot showing that adequate AMR launch trajectory coverage, from practically lift-off to orbital insertion, is achievable by AROD configurations A-D. Note that, for the stipulated station location uncertainties (see Table 1.1), AROD position system accuracies

Table 1.1

TEST RUN SPECIFICATION

Run No.	Configuration	Range Meas. Error, σ_r (meters)	Range Rate Meas. Error, $\sigma_{\dot{r}}$ (m/sec)	Ocean Borne Long. & Lat. Errors, σ_ℓ (meters)	Ocean Borne Altitude Errors, σ_h (meters)	All Land based Errors, (meters)	Min. Elev. Angle (degrees)
21	D	3	0.05	0	0	---	5
22	D			30	3	---	
23	D			100	10	---	
24	A			100	10	3	
25	B			100	10	10	
26	C			100	10	10	
27	A			30	3	3	
28	B			30	3	3	
29	C			30	3	3	
30	E			---	---	3	
31	F			---	---	3	
32	G			---	---	3 (SS, CH) 10 (Ber)	
33	H			30	10	10	
34	H			100	10	10	
35	I			30	10	---	
36	I			100	10	---	
37	J			---	---	0.03	
38	J			---	---	0.10	
39	I			300	10	---	
40	I			1000	10	---	
41	I	10	0.15	30	10	---	
42	I	10	0.15	100	10	---	
43	I	3	0.05	30	3	---	
44	K			30	10	---	
45	K			100	10	---	
46	L			30	10	---	
47	L			100	10	---	

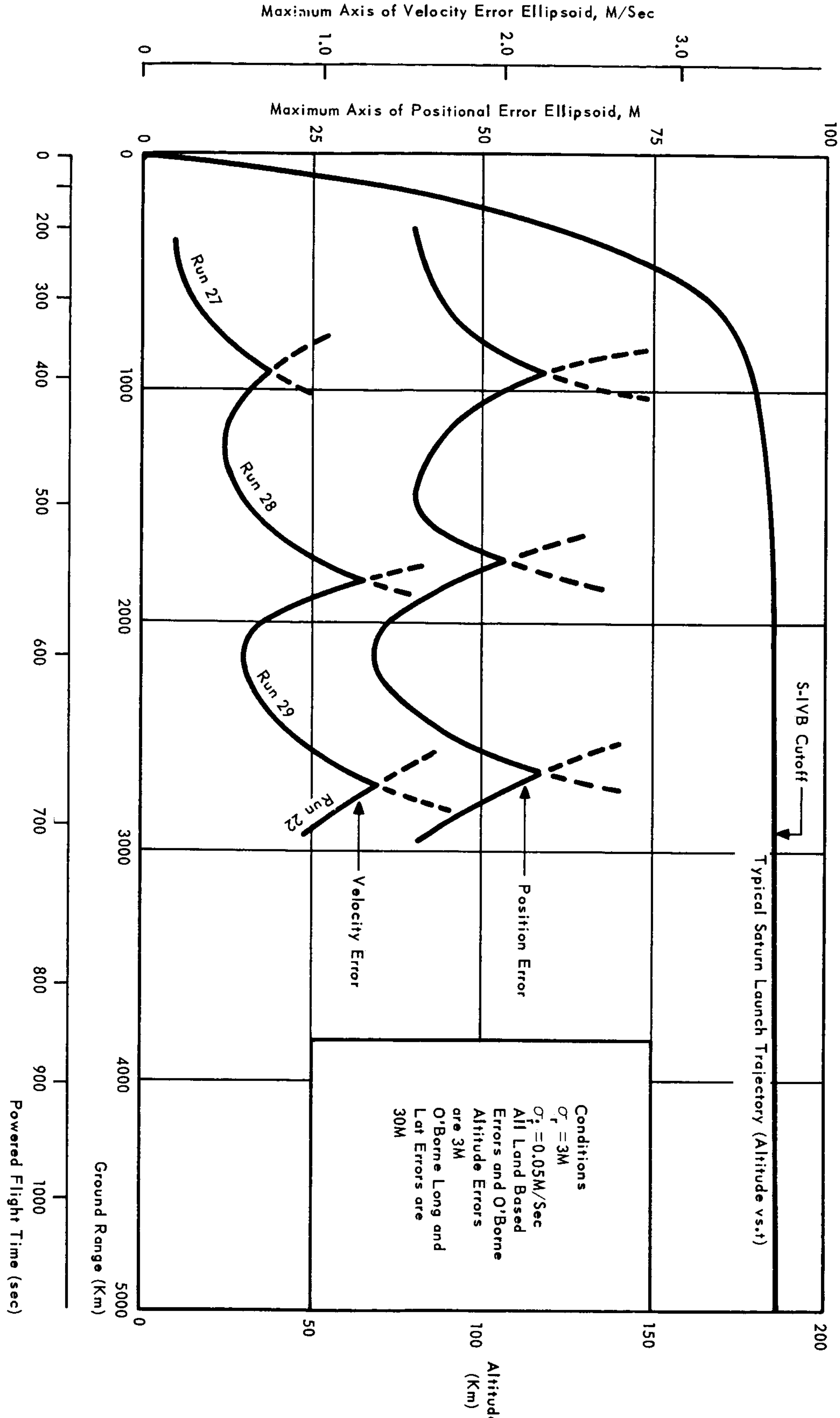


Figure 1.12. COMPOSITE PERFORMANCE OF SEVERAL DOWN RANGE AROD CONFIGURATIONS DURING TYPICAL AMR LAUNCH

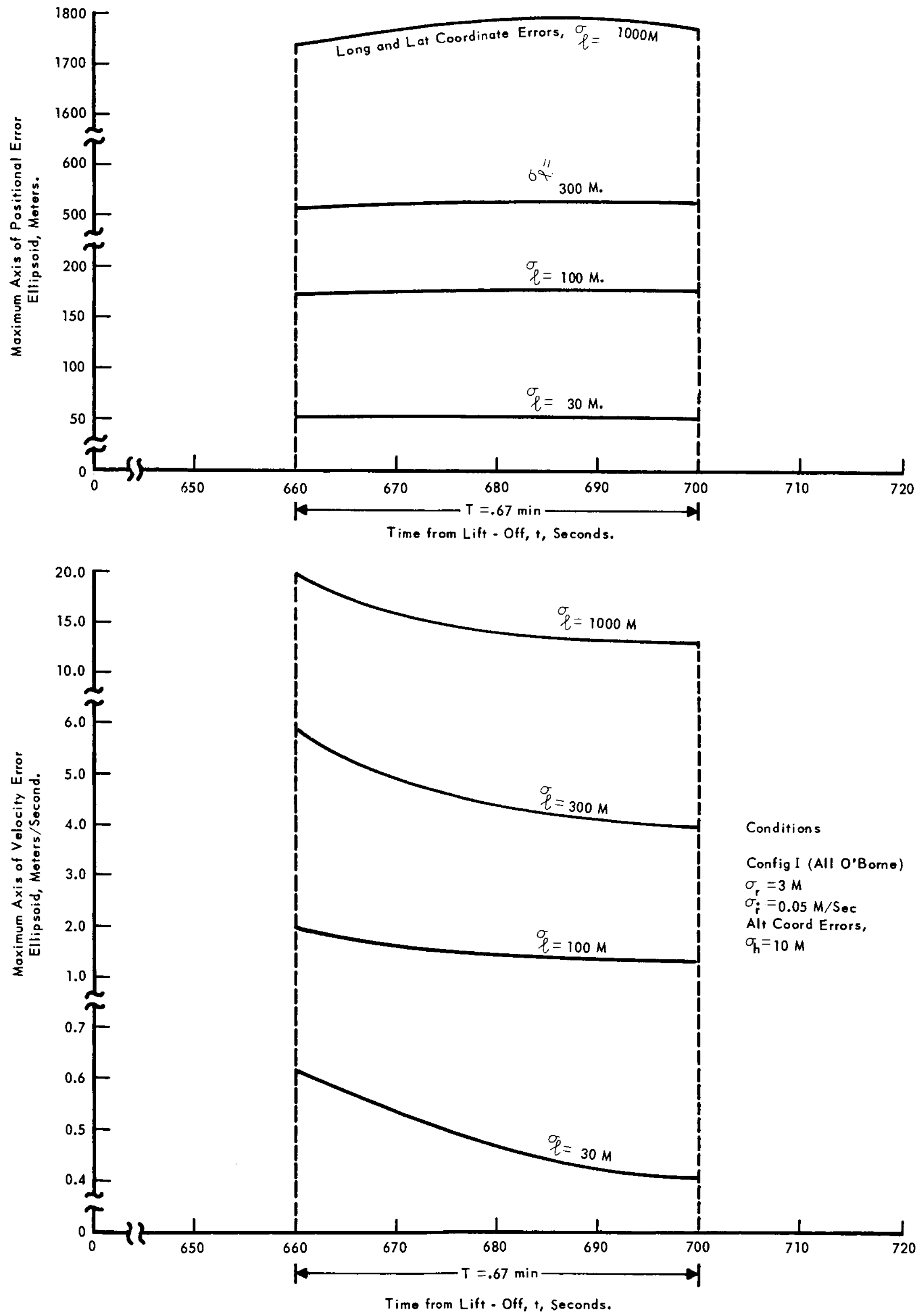


Figure 1.13. EFFECTS OF STATION COORDINATE ERRORS ON OCEANBORNE CONFIGURATION PERFORMANCE (RUNS 35, 36, 39, 40)

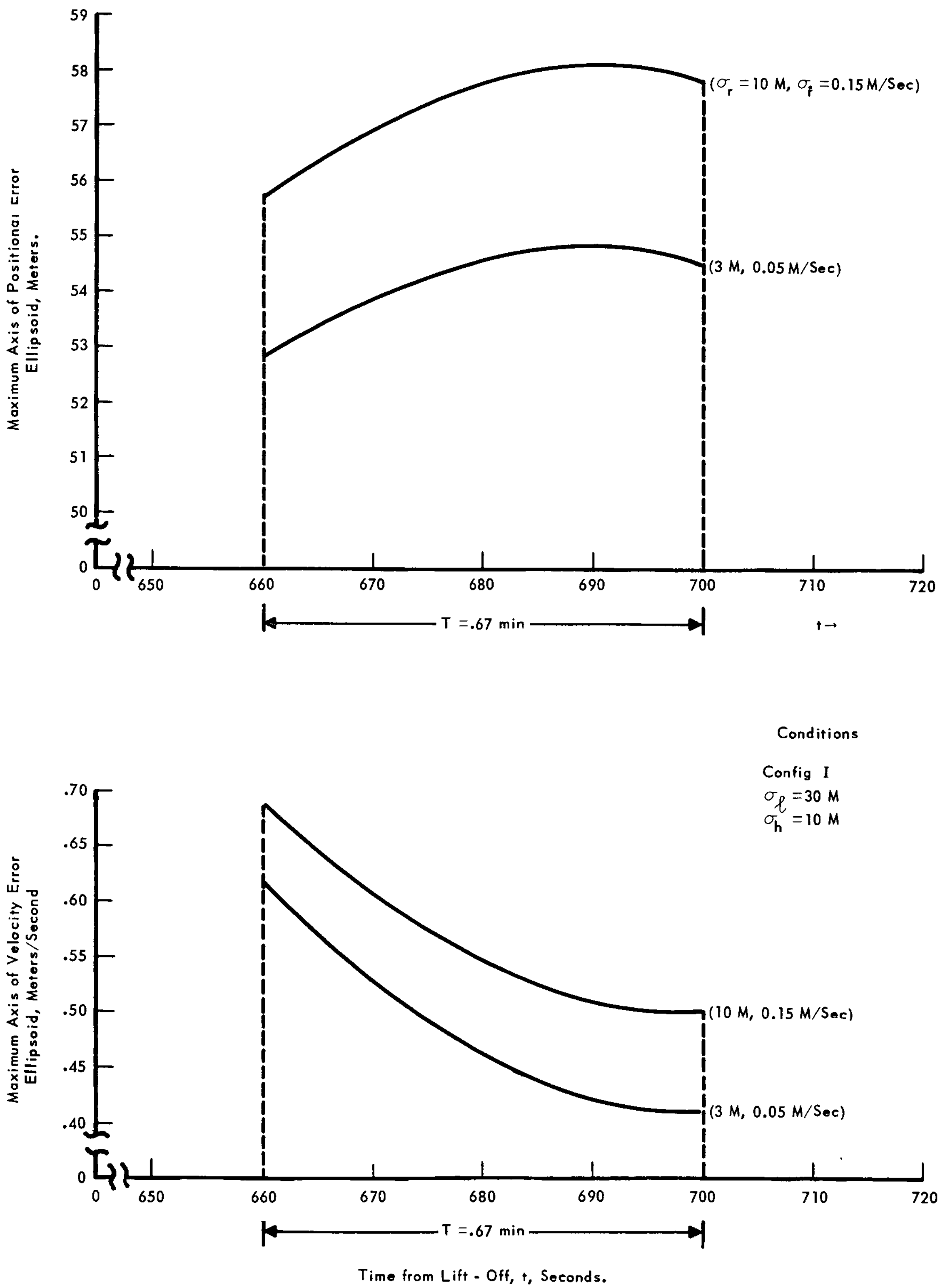


Figure 1.14. EFFECTS OF CHANGES IN AROD MEASUREMENT ACCURACIES ON OCEANBORNE PERFORMANCE (RUNS 35, 41)

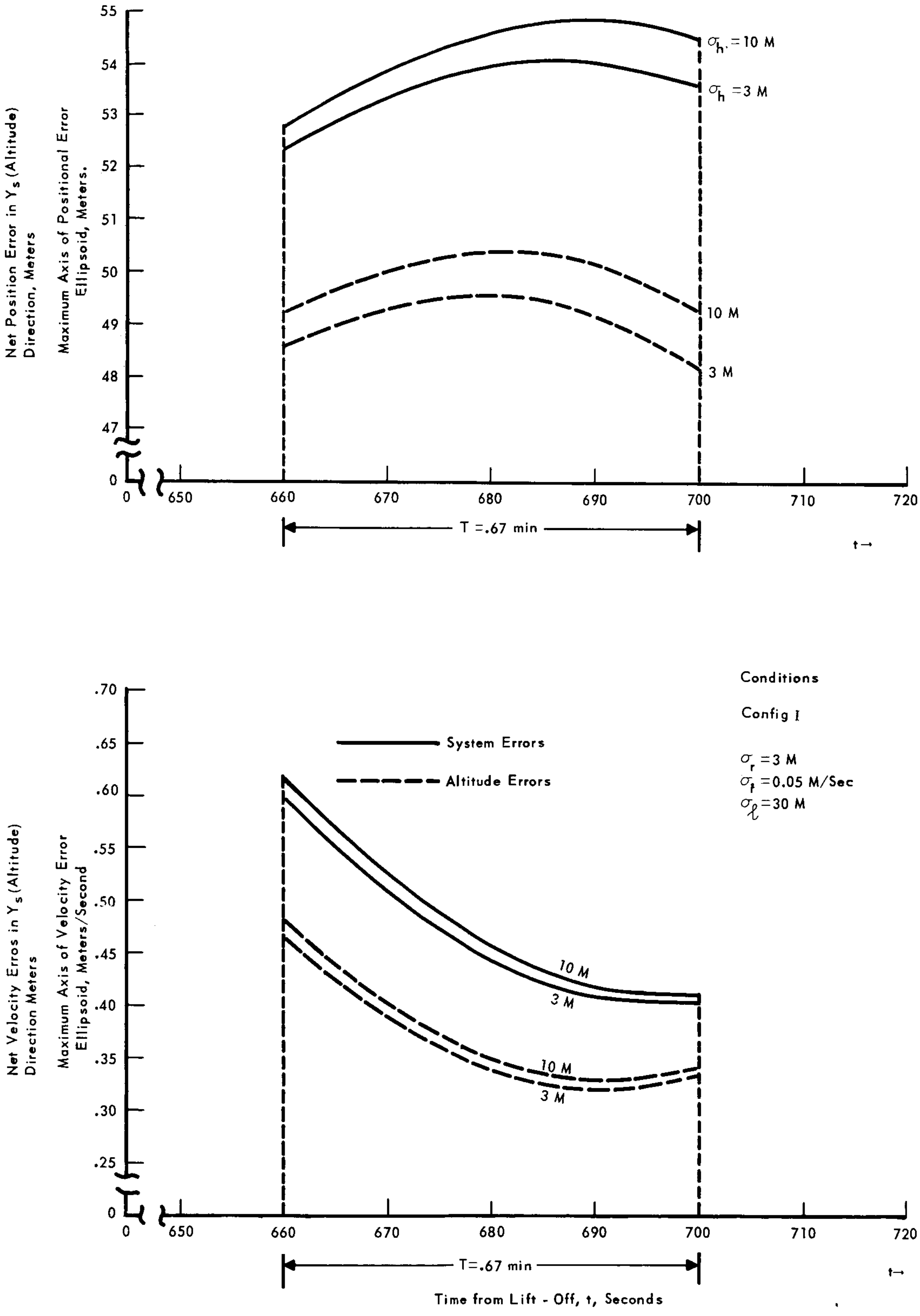


Figure 1.15. EFFECTS OF STATION ALTITUDE COORINDATE ERRORS ON OCEANBORNE PERFORMANCE (RUNS 35, 43)

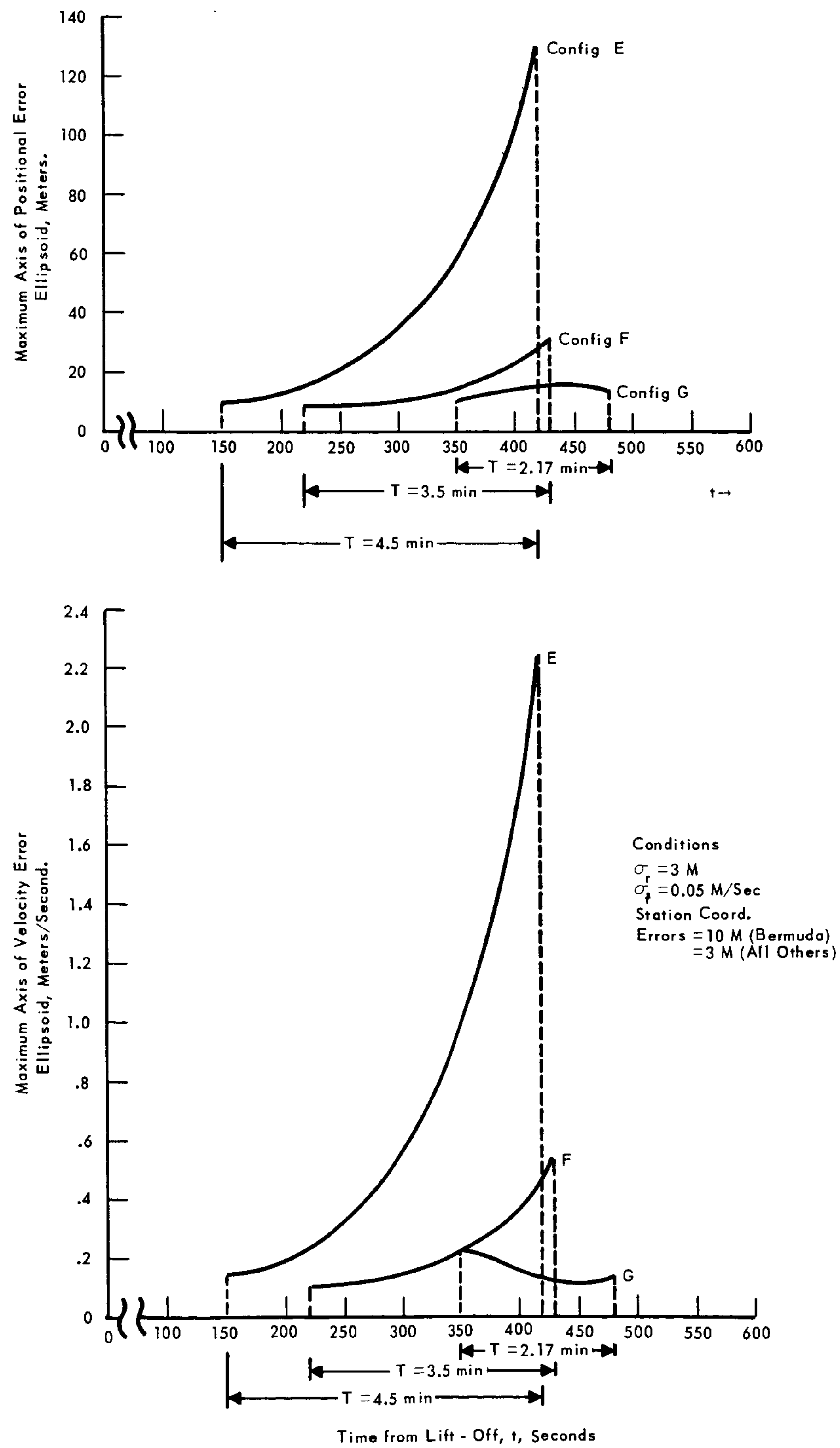


Figure 1.16. COMPARISON OF THREE OFFSHORE LAND-BASED CONFIGURATIONS (RUNS 30, 31, 32)

of the order of 45 meters and AROD velocity system accuracies of the order of 1 M/sec are available throughout the typical Saturn launch trajectory.

The importance of minimizing oceanborne station coordinate uncertainties is illustrated in Figure 1.13. This figure gives time history plots of the position and velocity system errors associated with Configuration I (All Oceanborne), over a wide range of values of longitude and latitude station coordinate errors (σ_{ℓ} = 30, 100, 300, 1000 meters). Altitude coordinate errors σ_h are assumed equal at 10M for each transponder of Configuration I and "representative" values of AROD range/range-rate measurement errors (σ_r = 3M, $\sigma_{\dot{r}}$ = 0.05 M/sec) are assumed in Figure 1.13. Results of Figure 1.13 indicate that for the representative values of (σ_r, $\sigma_{\dot{r}}$), AROD system errors are roughly proportional to σ_{ℓ}: system position (velocity) error is approximately 55M (0.5 M/sec) for σ_{ℓ} = 30M and approximately 1800M(15 M/sec) for σ_{ℓ} = 1000M. An approximate rule-of-thumb then is that, for oceanborne transponder configurations (with baselines of the order of 800 - 1000 km),

AROD Position System Error $\approx 2\sigma_{\ell}$

AROD Velocity System Error $\approx 0.02\sigma_{\ell}$

for values of σ_{ℓ} greater than 30 meters.

The strong influence baseline distance has on the performance of AROD oceanborne configurations is demonstrated by comparing the results of runs 35, 44, and 46. In these runs, oceanborne configurations I, K, and L represent large (1000 KM), medium (400 KM), and small (100 KM) baseline configurations, respectively Representative measurement accuracies, station longitude-latitude errors of σ_{ℓ} = 30M, and station altitude errors of σ_h = 10M are also assumed in these runs. It is noted that although coverage time is greatly increased with decreasing base line, system accuracy is generally poorer and varies over a wider range. Thus, large baselines are generally preferable for oceanborne deployment, except where coverage time is critical.

First estimates of the relative importance of AROD measurement accuracies, in the presence of oceanborne station location uncertainties, are supplied by Figure 1.14. System error time plots are given for two combinations of measurement accuracies (3M, 0.05 M/sec and 10M, 0.15 M/sec), with oceanborne configuration I, and for $\sigma_{\ell} = 30M$, $\sigma_h = 10M$. Variations in system performance, for the large changes in magnitude of (σ_r, $\sigma_{\dot{r}}$), are seen to be relatively small in the presence of station coordinate errors of the order of 30M. For larger values of station coordinate errors, system performance variations as a result of changes in (σ_r, $\sigma_{\dot{r}}$) will be even smaller than those shown in Figure 1.14. Thus, for oceanborne deployment of transponders the design requirements on measurement accuracy (σ_r, $\sigma_{\dot{r}}$) can probably be related with little effect on overall system accuracy.

Owing to the tactical advantages of mid-range land-based configurations, a configuration employing three stations on Bermuda (Bermuda Baseline) was evaluated in the test runs. The performance of the Bermuda Baseline configuration can be compared to (all oceanborne) Configuration I by examining the results of computer runs 35, 36, 37, 39 and 40. It is clear from the results that the Bermuda Baseline configuration cannot compete with large baseline oceanborne configurations except possibly when $\sigma_{\ell} > 100M$. The errors resulting from the bias error expected in surveying the three Bermuda stations, as supplied by the computer program (see print-out data, paragraph 1.2.4), are as expected: net system positional bias error in the X_s (i.e., approximately longitudinal direction is 15M and net system velocity bias error is zero.

To assess the effects of altitude coordinate errors on oceanborne configuration performance, Figure 1.15 plots system errors for two values of σ_h (3M, 10M) associated with Configuration I. In addition to ellipsoidal maximum axis data, Figure 1.15 also gives the variation of net system error in the topocentric Y_s (essentially altitude) direction. Representative measurement errors and longitude-latitude station coordinate errors of $\sigma_{\ell} = 30M$ are assumed in Figure 1.15. Results given in Figure 1.15 indicate that changes in σ_h have small effect on net system performance.

An all land-based offshore-Florida configuration has obvious tactical and operational advantages. Three transponder configurations employed in these first test runs are of this nature: Configurations E, F, and G. Of the three, Configuration E is of relatively short base-line; Configurations F and G are each of relatively large base-line, with F possessing the additional advantage of early coverage capability. System errors for these three configurations are plotted in Figure 1.16. Station coordinate errors of 3M are assumed for all locations except Bermuda, for which station coordinate errors of 10M are assumed; representative measurement errors are assumed in Figure 1.16. The data of Figure 1.16 indicate that early land-based AMR coverage, of acceptable accuracy, is available through AROD configurations E, F, G. Comparatively, it may be deduced that the larger baseline configurations are to be employed whenever permitted by coverage requirements.

Figure 1.17 (3 sheets) displays the ranges of the AROD position and velocity system errors for runs 21-47. This figure serves as a useful data summary since the shapes of the curves are usually similar.

1.2.3 Summary of Computer Results

Important preliminary conclusions resulting from the preceding computer results can be summarized as follows:

- Continuous coverage of AMR launch trajectories (from essentially lift-off to orbital insertion) can be obtained from a transponder network comprising land-based and a few oceanborne transponders.

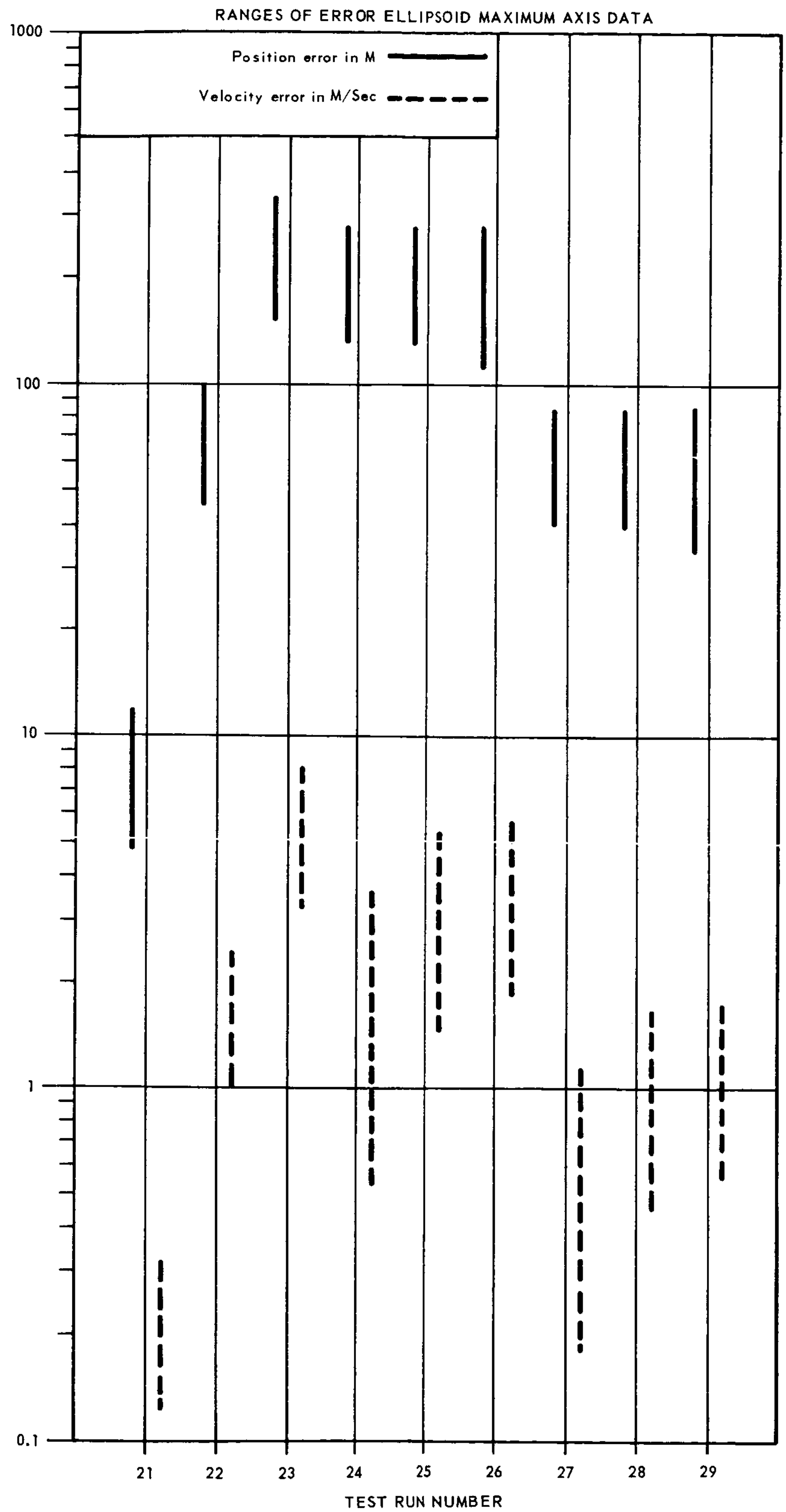


Figure 1.17 RANGE OF DATA (SEMI-LOG) GRAPHS (Sheet 1)

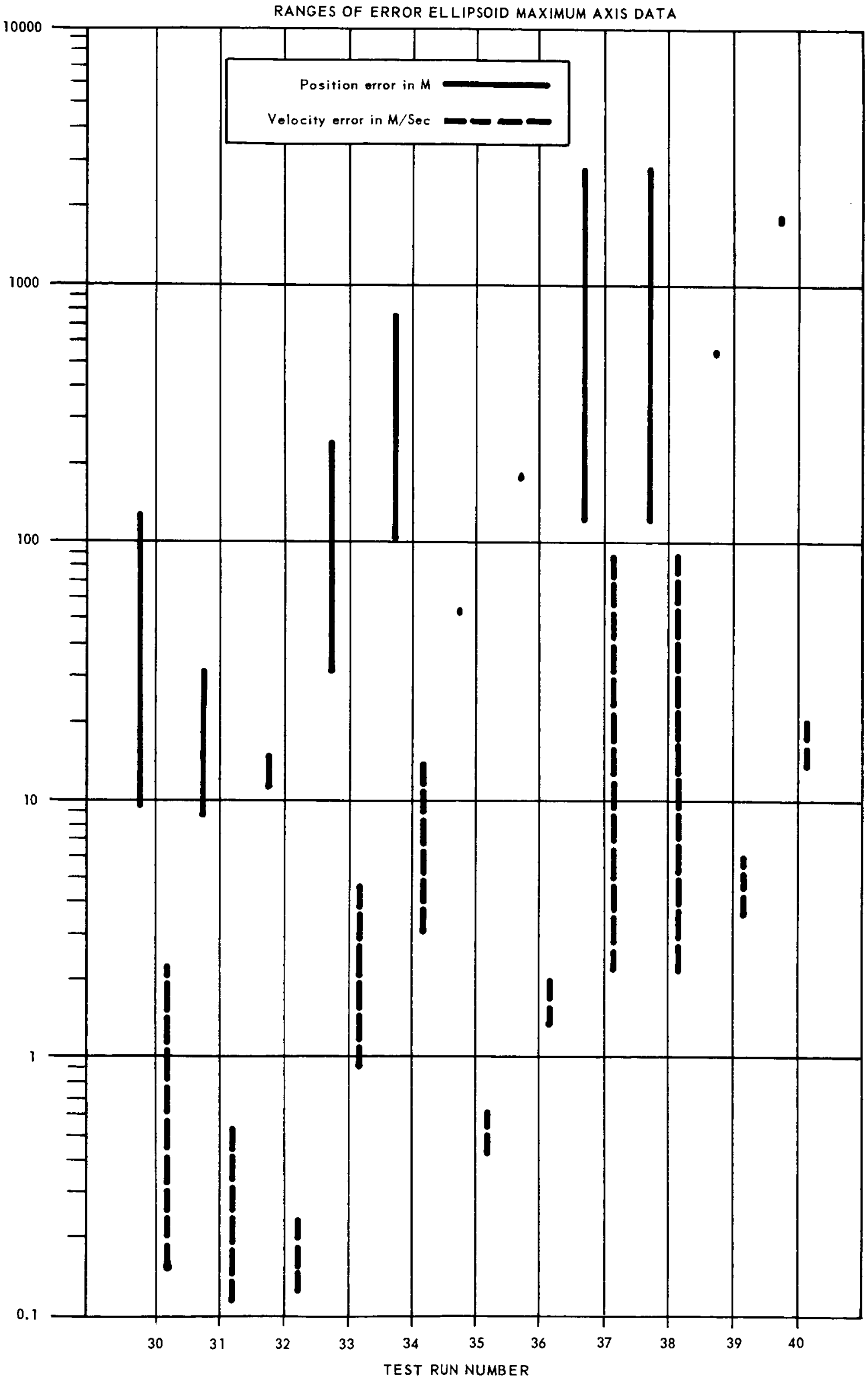


Figure 1.17 RANGE OF DATA (SEMI-LOG) GRAPHS (Sheet 2)

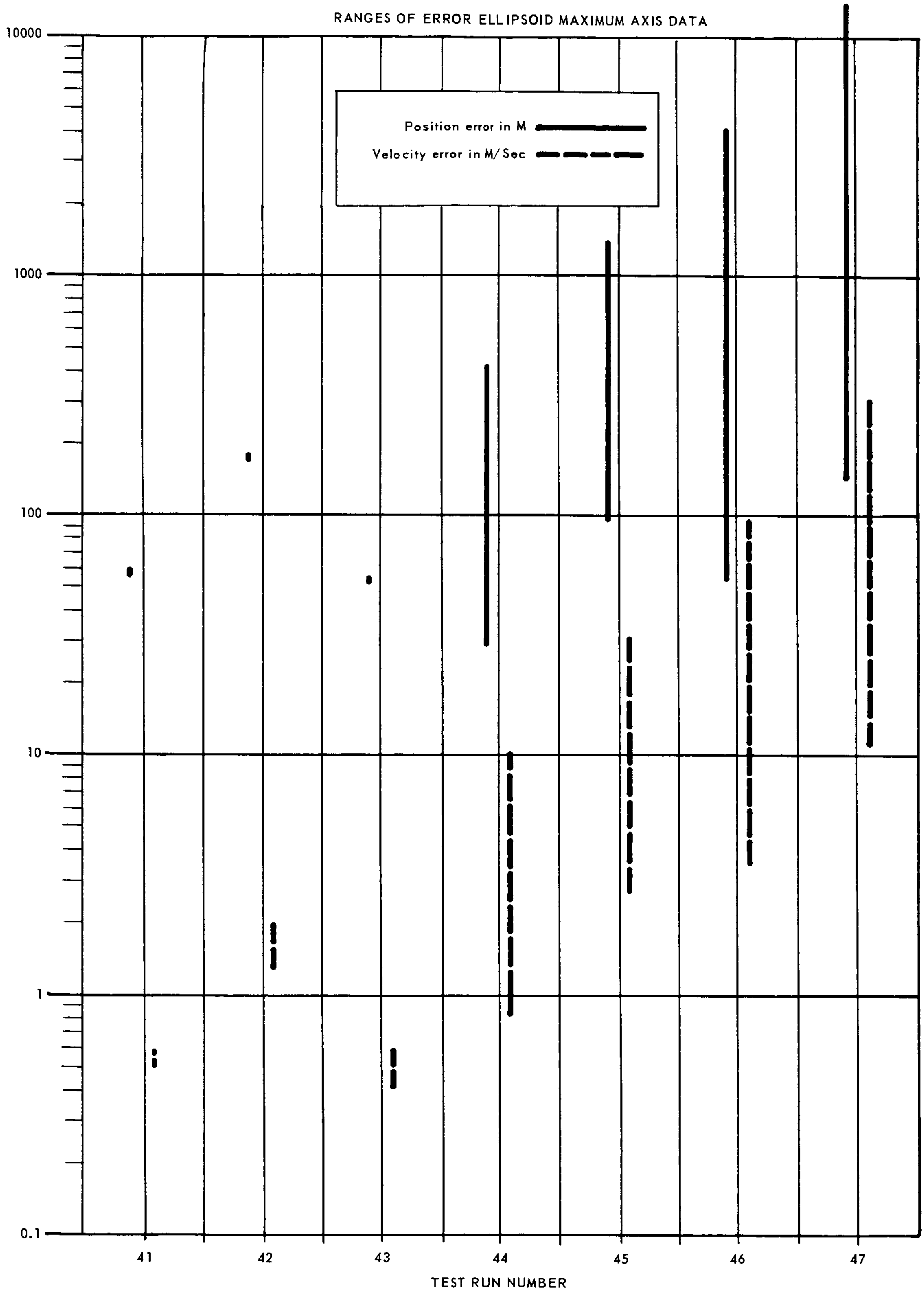


Figure 1.17 RANGE OF DATA (SEMI-LOG) GRAPHS (Sheet 3)

• AROD position and velocity system errors are essentially proportional to station coordinate errors for oceanborne transponder configurations.

• For oceanborne configurations, large baselines ($\approx$ 800 km) should be employed whenever permitted by coverage requirements.

• In the presence of oceanborne station coordinate errors greater than 30 meters, only small changes in system performance result from large changes in AROD range/range rate measurement accuracies (σ_r, $\sigma_{\dot{r}}$). Relatively rough design goals may thus be acceptable for these quantities.

• An all-Bermuda based AROD transponder triad is competitive (on a system accuracy basis) with a large-baseline oceanborne triad only in the presence of oceanborne station coordinate errors greater than 100 meters.

• Oceanborne station altitude errors, which are smaller than the latitude and longitude errors, have a correspondingly small effect on net AROD system errors.

• Early coverage of AMR launch trajectories, using all land-based transponders, is both possible and desirable. Three such configurations have been examined. Whenever permitted by coverage requirements, employment of the larger baseline configurations is preferred since these minimize GDOP effects.

It is emphasized that results presented here are of an early, preliminary nature. Several additional GDOP and operational aspects of AROD, as an AMR launch trajectory monitoring system, remain to be investigated in the next quarterly reporting period.

1.2.4 Computer Printouts

Figures 1.18 to 1.44 show the computer printouts of data summarizing the GDOP analyses, with the individual runs numbered 21 - 47. The first two groups of data for each run are input parameters (R, LONG, LAT, etc) needed to specify the locations of the three AROD transponders, and the geodetic and measurement accuracies being evaluated. Following the specification of the input parameters, the more important quantities computed by the error analysis program are presented for each time increment within the elevation-angle-limited period of observation. Table 1.2 gives a glossary of the terms used in these printouts.

Table 1.2

GLOSSARY OF PRINTOUT TERMS

RHO	-	Radius of a sphere with the same volume as the error ellipsoid (meters)*
DEL X	-	Bias error in X_s direction (meters)
X ERROR	-	Length of the semi-axis of the error ellipsoid in the X_s direction (meters)
Y ERROR	-	Length of the semi-axis of the error ellipsoid in the Y_s direction (meters)
Z ERROR	-	Length of the semi-axis of the error ellipsoid in the Z_s direction (meters)
MAX AX	-	Maximum principal semi-axis of the error ellipsoid (meters)
MIN AX	-	Minimum principal semi-axis of the error ellipsoid (meters)

*The units for the velocity parameters, meters per second, have been omitted for brevity.

Table 1.2—(Continued).

AZ MAX	-	Azimuth angle of the maximum principal axis (deg)
EL MAX	-	Elevation angle of the maximum principal axis (deg)
R	-	Range from center of earth to transponder (meters)
LONG	-	Longitude of transponder (deg)
LAT	-	Latitude of transponder (deg)
MIN EL	-	Minimum elevation angle (deg)
DEL R	-	Bias error in range (meters)
DEL RDOT	-	Bias error in range rate (meters/sec)
DEL X	-	Transponder location bias error in X_s direction (meters)
DEL Y	-	Transponder location bias error in Y_s direction (meters)
DEL Z	-	Transponder location bias error in Z_s direction (meters)
SIGMA R	-	RMS range error (meters)
SIGMA RDOT	-	RMS range rate error (meters/sec)
SIGMA X	-	Transponder RMS location error in X_s direction (meters)
SIGMA Y	-	Transponder RMS location error in Y_s direction (meters)
SIGMA Z	-	Transponder RMS location error in Z_s direction (meters)
XS	-	x coordinate of the transponder in the topocentric co-ordinate system
YS	-	y coordinate of the transponder in the topocentric co-ordinate systems
ZS	-	z coordinate of the transponder in the topocentric co-ordinate system

RUN NO.= 21 OCEANBORNE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-55.10000	38.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-53.10000	29.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-46.30000	35.30000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	-0.	-0.	-0.	2.4413711E 06	-5.1163149E 05	-5.4511206E 05
3.0000000E 00	4.9999999E-02	-0.	-0.	-0.	2.5450330E 06	-5.4899612E 05	4.6552765E 05
3.0000000E 00	4.9999999E-02	-0.	-0.	-0.	3.1422684E 06	-8.3291687E 05	-2.1312459E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
630.	POS	4.139E 00	0.	8.368E 00	8.288E 00	2.499E 00	1.152E 01	2.385E 00	45.	-1.
	VEL	9.709E-02	-0.	1.916E-01	2.590E-01	4.425E-02	3.173E-01	4.321E-02	54.	-1.
640.	POS	3.890E 00	0.	7.177E 00	6.643E 00	2.384E 00	9.420E 00	2.361E 00	42.	-0.
	VEL	8.505E-02	-0.	1.656E-01	2.154E-01	4.160E-02	2.658E-01	4.078E-02	53.	-1.
650.	POS	3.684E 00	-0.	6.163E 00	5.469E 00	2.302E 00	7.747E 00	2.289E 00	41.	1.
	VEL	7.899E-02	0.	1.431E-01	1.801E-01	3.950E-02	2.230E-01	3.882E-02	52.	-1.
660.	POS	3.522E 00	-0.	5.316E 00	4.749E 00	2.258E 00	6.462E 00	2.236E 00	40.	2.
	VEL	7.402E-02	0.	1.239E-01	1.524E-01	3.821E-02	1.879E-01	3.750E-02	52.	-1.
670.	POS	3.408E 00	-0.	4.624E 00	4.427E 00	2.255E 00	5.546E 00	2.209E 00	42.	3.
	VEL	7.030E-02	0.	1.078E-01	1.321E-01	3.800E-02	1.603E-01	3.700E-02	53.	-1.
680.	POS	3.338E 00	-0.	4.081E 00	4.395E 00	2.294E 00	4.998E 00	2.206E 00	50.	2.
	VEL	6.787E-02	0.	9.460E-02	1.188E-01	3.900E-02	1.401E-01	3.733E-02	54.	-2.
690.	POS	3.309E 00	-0.	3.672E 00	4.532E 00	2.375E 00	4.826E 00	2.219E 00	62.	-1.
	VEL	6.665E-02	0.	8.411E-02	1.123E-01	4.111E-02	1.273E-01	3.826E-02	58.	-3.
700.	POS	3.312E 00	-0.	3.380E 00	4.751E 00	2.495E 00	4.941E 00	2.237E 00	71.	-6.
	VEL	6.642E-02	0.	7.609E-02	1.116E-01	4.407E-02	1.222E-01	3.947E-02	63.	-6.

Figure 1.18 SUMMARY DATA FOR RUN NO. 21

RUN NO.= 22 OCEANBORNE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-55.10000	38.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-53.10000	29.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-46.30000	35.30000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.4413711E 06	-5.1163149E 05	-5.4511206E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.5450330E 06	-5.4899612E 05	4.6552765E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	3.1422684E 06	-8.3291687E 05	-2.1312459E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
630.	POS	3.580E 01	0.	7.216E 01	7.257E 01	2.207E 01	1.002E 02	2.066E 01	45.	1.
	VEL	4.737E-01	-0.	1.285E 00	2.023E 00	2.869E-01	2.391E 00	1.523E-01	58.	-2.
640.	POS	3.378E 01	0.	6.219E 01	5.897E 01	2.133E 01	8.288E 01	2.106E 01	43.	1.
	VEL	4.617E-01	-0.	1.136E 00	1.716E 00	2.873E-01	2.051E 00	1.628E-01	57.	-2.
650.	POS	3.721E 01	-0.	5.393E 01	4.943E 01	2.097E 01	6.943E 01	2.058E 01	42.	3.
	VEL	4.523E-01	0.	1.006E 00	1.455E 00	2.880E-01	1.758E 00	1.758E-01	56.	-3.
660.	POS	3.110E 01	-0.	4.726E 01	4.352E 01	2.100E 01	5.945E 01	2.025E 01	42.	4.
	VEL	4.453E-01	0.	8.896E-01	1.237E 00	2.888E-01	1.508E 00	1.913E-01	55.	-3.
670.	POS	3.041E 01	-0.	4.202E 01	4.057E 01	2.143E 01	5.250E 01	2.007E 01	43.	5.
	VEL	4.405E-01	0.	7.854E-01	1.061E 00	2.899E-01	1.297E 00	2.084E-01	54.	-5.
680.	POS	3.008E 01	-0.	3.808E 01	3.966E 01	2.223E 01	4.809E 01	1.993E 01	47.	4.
	VEL	4.380E-01	0.	6.915E-01	9.325E-01	2.912E-01	1.128E 00	2.248E-01	55.	-6.
690.	POS	3.003E 01	-0.	3.522E 01	3.996E 01	2.338E 01	4.578E 01	1.974E 01	53.	0.
	VEL	4.377E-01	0.	6.076E-01	8.633E-01	2.927E-01	1.011E 00	2.374E-01	58.	-8.
700.	POS	3.018E 01	-0.	3.320E 01	4.100E 01	2.482E 01	4.530E 01	1.951E 01	60.	-7.
	VEL	4.396E-01	0.	5.351E-01	8.634E-01	2.944E-01	9.638E-01	2.448E-01	63.	-10.

Figure 1.19 SUMMARY DATA FOR RUN NO. 22

RUN NO.= 23 OCEANBORNE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-55.10000	38.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-53.10000	29.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-46.30000	35.30000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.4413711E 06	-5.1163149E 05	-5.4511206E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.5450330E 06	-5.4899612E 05	4.6552765E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	3.1422684E 06	-8.3291687E 05	-2.1312459E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
630.	POS	1.186E 02	0.	2.391E 02	2.405E 02	7.312E 01	3.320E 02	6.842E 01	45.	1.
	VEL	1.533E 00	-0.	4.241E 00	6.693E 00	9.459E-01	7.908E 00	4.744E-01	58.	-2.
640.	POS	1.119E 02	0.	2.060E 02	1.954E 02	7.071E 01	2.746E 02	6.980E 01	43.	1.
	VEL	1.502E 00	-0.	3.751E 00	5.679E 00	9.486E-01	6.783E 00	5.140E-01	57.	-2.
650.	POS	1.067E 02	-0.	1.787E 02	1.638E 02	6.952E 01	2.301E 02	6.821E 01	42.	3.
	VEL	1.477E 00	0.	3.321E 00	4.817E 00	9.517E-01	5.819E 00	5.619E-01	56.	-3.
660.	POS	1.030E 02	-0.	1.566E 02	1.443E 02	6.964E 01	1.971E 02	6.712E 01	42.	4.
	VEL	1.459E 00	0.	2.939E 00	4.094E 00	9.550E-01	4.991E 00	6.180E-01	55.	-3.
670.	POS	1.008E 02	-0.	1.393E 02	1.345E 02	7.107E 01	1.741E 02	6.651E 01	43.	5.
	VEL	1.448E 00	0.	2.596E 00	3.510E 00	9.587E-01	4.293E 00	6.791E-01	54.	-5.
680.	POS	9.970E 01	-0.	1.263E 02	1.314E 02	7.374E 01	1.595E 02	6.602E 01	47.	4.
	VEL	1.447E 00	0.	2.285E 00	3.085E 00	9.626E-01	3.733E 00	7.370E-01	55.	-6.
690.	POS	9.954E 01	-0.	1.168E 02	1.324E 02	7.755E 01	1.518E 02	6.539E 01	52.	0.
	VEL	1.443E 00	0.	2.008E 00	2.855E 00	9.667E-01	3.345E 00	7.811E-01	58.	-8.
700.	POS	1.000E 02	-0.	1.101E 02	1.358E 02	8.235E 01	1.502E 02	6.462E 01	60.	-7.
	VEL	1.449E 00	0.	1.767E 00	2.856E 00	9.711E-01	3.189E 00	8.056E-01	63.	-10.

Figure 1.20 SUMMARY DATA FOR RUN NO. 23

RUN NO.= 24 OFFSHORE FLA

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-79.50000	28.60000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-72.90000	35.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-70.60000	26.40000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	9.2970390E 04	-7.4825000E 02	2.9779000E 04
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	8.8267585E 05	-7.9955437E 04	-4.8299146E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	8.7010127E 05	-7.9302625E 04	4.9709765E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
220.	POS	3.884E 01	-0.	5.422E 01	1.189E 02	1.058E 02	1.306E 02	4.240E 00	294.	-1.
	VEL	3.923E-01	0.	2.852E-01	5.355E-01	4.311E-01	5.629E-01	2.609E-01	76.	20.
230.	POS	3.870E 01	-0.	5.185E 01	1.227E 02	1.027E 02	1.331E 02	4.240E 00	293.	-1.
	VEL	3.968E-01	0.	2.832E-01	5.197E-01	4.407E-01	5.388E-01	2.741E-01	81.	22.
240.	POS	3.851E 01	-0.	4.954E 01	1.260E 02	9.951E 01	1.354E 02	4.240E 00	291.	-1.
	VEL	4.031E-01	0.	2.820E-01	5.225E-01	4.504E-01	5.336E-01	2.800E-01	86.	20.
250.	POS	3.829E 01	-0.	4.729E 01	1.290E 02	9.639E 01	1.374E 02	4.240E 00	290.	-1.
	VEL	4.109E-01	0.	2.812E-01	5.409E-01	4.605E-01	5.467E-01	2.790E-01	272.	-15.
260.	POS	3.805E 01	-0.	4.509E 01	1.318E 02	9.332E 01	1.392E 02	4.241E 00	289.	-1.
	VEL	4.201E-01	0.	2.807E-01	5.729E-01	4.707E-01	5.775E-01	2.736E-01	276.	-8.
270.	POS	3.779E 01	-0.	4.296E 01	1.343E 02	9.032E 01	1.409E 02	4.241E 00	288.	-1.
	VEL	4.306E-01	0.	2.803E-01	6.169E-01	4.813E-01	6.231E-01	2.661E-01	278.	-3.
280.	POS	3.753E 01	-0.	4.090E 01	1.367E 02	8.741E 01	1.426E 02	4.241E 00	287.	-1.
	VEL	4.423E-01	0.	2.798E-01	6.721E-01	4.922E-01	6.804E-01	2.581E-01	280.	-1.
290.	POS	3.728E 01	-0.	3.892E 01	1.391E 02	8.461E 01	1.444E 02	4.241E 00	286.	-1.
	VEL	4.551E-01	0.	2.792E-01	7.380E-01	5.033E-01	7.481E-01	2.502E-01	280.	0.
300.	POS	3.704E 01	-0.	3.702E 01	1.416E 02	8.197E 01	1.463E 02	4.241E 00	285.	-1.
	VEL	4.691E-01	0.	2.783E-01	8.148E-01	5.148E-01	8.260E-01	2.428E-01	280.	1.
310.	POS	3.685E 01	-0.	3.521E 01	1.442E 02	7.950E 01	1.485E 02	4.242E 00	284.	-1.
	VEL	4.844E-01	0.	2.770E-01	9.030E-01	5.266E-01	9.147E-01	2.361E-01	279.	1.
320.	POS	3.670E 01	-0.	3.352E 01	1.473E 02	7.725E 01	1.510E 02	4.242E 00	283.	-2.
	VEL	5.009E-01	0.	2.751E-01	1.004E 00	5.387E-01	1.015E 00	2.300E-01	279.	2.
330.	POS	3.663E 01	-0.	3.194E 01	1.508E 02	7.527E 01	1.541E 02	4.242E 00	282.	-2.
	VEL	5.187E-01	0.	2.727E-01	1.118E 00	5.512E-01	1.129E 00	2.246E-01	278.	2.
340.	POS	3.665E 01	-0.	3.049E 01	1.550E 02	7.361E 01	1.580E 02	4.242E 00	281.	-2.
	VEL	5.378E-01	0.	2.695E-01	1.247E 00	5.640E-01	1.257E 00	2.198E-01	277.	2.
350.	POS	3.680E 01	-0.	2.917E 01	1.602E 02	7.231E 01	1.629E 02	4.243E 00	280.	-2.
	VEL	5.585E-01	0.	2.654E-01	1.394E 00	5.772E-01	1.403E 00	2.156E-01	276.	2.
360.	POS	3.710E 01	-0.	2.800E 01	1.666E 02	7.143E 01	1.690E 02	4.243E 00	279.	-2.
	VEL	5.808E-01	0.	2.604E-01	1.560E 00	5.909E-01	1.568E 00	2.119E-01	276.	2.
370.	POS	3.758E 01	-0.	2.696E 01	1.746E 02	7.101E 01	1.767E 02	4.243E 00	279.	-2.
	VEL	6.048E-01	0.	2.542E-01	1.750E 00	6.049E-01	1.756E 00	2.087E-01	275.	1.
380.	POS	3.827E 01	-0.	2.604E 01	1.846E 02	7.109E 01	1.864E 02	4.243E 00	278.	-2.
	VEL	6.307E-01	0.	2.468E-01	1.966E 00	6.194E-01	1.972E 00	2.059E-01	274.	1.
390.	POS	3.920E 01	-0.	2.523E 01	1.969E 02	7.173E 01	1.985E 02	4.242E 00	277.	-2.
	VEL	6.588E-01	0.	2.383E-01	2.215E 00	6.344E-01	2.219E 00	2.036E-01	273.	1.
400.	POS	4.038E 01	-0.	2.450E 01	2.120E 02	7.293E 01	2.134E 02	4.242E 00	276.	-2.
	VEL	6.893E-01	0.	2.286E-01	2.501E 00	6.499E-01	2.504E 00	2.018E-01	272.	1.
410.	POS	4.184E 01	-0.	2.380E 01	2.304E 02	7.471E 01	2.316E 02	4.242E 00	276.	-1.
	VEL	7.224E-01	0.	2.183E-01	2.832E 00	6.660E-01	2.834E 00	2.003E-01	272.	1.
420.	POS	4.359E 01	-0.	2.308E 01	2.527E 02	7.707E 01	2.538E 02	4.241E 00	275.	-1.
	VEL	7.586E-01	0.	2.083E-01	3.218E 00	6.826E-01	3.219E 00	1.992E-01	271.	1.
430.	POS	4.564E 01	-0.	2.226E 01	2.797E 02	8.001E 01	2.805E 02	4.241E 00	274.	-1.
	VEL	7.983E-01	0.	2.006E-01	3.671E 00	6.997E-01	3.671E 00	1.986E-01	270.	1.

Figure 1.21 SUMMARY DATA FOR RUN NO. 24

RUN NO.= 25 EARLY BERM

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-72.00000	35.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-69.70000	26.40000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-63.10000	33.00000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	9.6156968E 05	-9.0034499E 04	-4.6313540E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	9.5634693E 05	-9.3441937E 04	5.1701484E 05
3.0000000E 00	4.9999999E-02	1.0000000E 01	1.0000000E 01	1.0000000E 01	1.7068307E 06	-2.3344556E 05	-8.2411875E 04

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
350.	POS	5.997E 01	0.	1.006E 02	2.546E 02	7.560E 01	2.735E 02	1.041E 01	69.	2.
	VEL	7.324E-01	-0.	9.387E-01	3.088E 00	5.782E-01	3.220E 00	2.096E-01	74.	1.
360.	POS	5.776E 01	0.	9.491E 01	2.316E 02	7.380E 01	2.500E 02	1.042E 01	68.	2.
	VEL	7.758E-01	-0.	8.930E-01	2.810E 00	5.916E-01	2.939E 00	2.180E-01	73.	1.
370.	POS	5.583E 01	0.	9.009E 01	2.116E 02	7.239E 01	2.297E 02	1.043E 01	67.	2.
	VEL	7.214E-01	-0.	8.530E-01	2.564E 00	6.054E-01	2.691E 00	2.281E-01	72.	0.
380.	POS	5.418E 01	0.	8.608E 01	1.944E 02	7.145E 01	2.122E 02	1.043E 01	66.	2.
	VEL	7.191E-01	-0.	8.175E-01	2.344E 00	6.197E-01	2.469E 00	2.400E-01	72.	0.
390.	POS	5.282E 01	0.	8.285E 01	1.796E 02	7.101E 01	1.973E 02	1.043E 01	65.	2.
	VEL	7.188E-01	-0.	7.855E-01	2.146E 00	6.345E-01	2.269E 00	2.543E-01	71.	-0.
400.	POS	5.175E 01	-0.	8.038E 01	1.670E 02	7.114E 01	1.847E 02	1.044E 01	65.	2.
	VEL	7.706E-01	0.	7.562E-01	1.968E 00	6.497E-01	2.088E 00	2.713E-01	70.	-1.
410.	POS	5.096E 01	-0.	7.863E 01	1.561E 02	7.186E 01	1.741E 02	1.044E 01	64.	2.
	VEL	7.244E-01	0.	7.287E-01	1.808E 00	6.655E-01	1.923E 00	2.916E-01	70.	-1.
420.	POS	5.044E 01	-0.	7.755E 01	1.468E 02	7.321E 01	1.651E 02	1.044E 01	63.	1.
	VEL	7.303E-01	0.	7.025E-01	1.666E 00	6.818E-01	1.775E 00	3.158E-01	70.	-3.
430.	POS	5.015E 01	-0.	7.707E 01	1.386E 02	7.519E 01	1.575E 02	1.043E 01	61.	1.
	VEL	7.383E-01	0.	6.768E-01	1.543E 00	6.987E-01	1.645E 00	3.443E-01	70.	-4.
440.	POS	5.006E 01	-0.	7.712E 01	1.312E 02	7.780E 01	1.508E 02	1.043E 01	60.	-0.
	VEL	7.486E-01	0.	6.513E-01	1.446E 00	7.163E-01	1.537E 00	3.774E-01	71.	-7.
450.	POS	5.011E 01	-0.	7.762E 01	1.242E 02	8.104E 01	1.448E 02	1.043E 01	59.	-2.
	VEL	7.613E-01	0.	6.252E-01	1.380E 00	7.345E-01	1.460E 00	4.145E-01	73.	-10.
460.	POS	5.027E 01	-0.	7.846E 01	1.175E 02	8.487E 01	1.393E 02	1.042E 01	58.	-4.
	VEL	7.766E-01	0.	5.982E-01	1.357E 00	7.533E-01	1.427E 00	4.534E-01	76.	-14.
470.	POS	5.047E 01	-0.	7.955E 01	1.107E 02	8.927E 01	1.341E 02	1.042E 01	56.	-9.
	VEL	7.945E-01	0.	5.698E-01	1.387E 00	7.730E-01	1.451E 00	4.888E-01	80.	-16.
480.	POS	5.067E 01	-0.	8.077E 01	1.038E 02	9.421E 01	1.296E 02	1.042E 01	56.	-16.
	VEL	8.155E-01	0.	5.397E-01	1.481E 00	7.934E-01	1.541E 00	5.091E-01	84.	-17.
490.	POS	5.082E 01	-0.	8.203E 01	9.707E 01	9.967E 01	1.271E 02	1.042E 01	59.	-28.
	VEL	8.398E-01	0.	5.078E-01	1.646E 00	8.146E-01	1.703E 00	5.013E-01	87.	-16.
500.	POS	5.092E 01	-0.	8.319E 01	9.101E 01	1.056E 02	1.286E 02	1.042E 01	66.	-42.
	VEL	8.676E-01	0.	4.745E-01	1.889E 00	8.368E-01	1.939E 00	4.705E-01	89.	-14.
510.	POS	5.100E 01	-0.	8.413E 01	8.708E 01	1.120E 02	1.349E 02	1.042E 01	75.	-51.
	VEL	8.996E-01	0.	4.414E-01	2.214E 00	8.600E-01	2.256E 00	4.322E-01	89.	-12.
520.	POS	5.122E 01	-0.	8.471E 01	8.770E 01	1.189E 02	1.448E 02	1.042E 01	84.	-54.
	VEL	9.361E-01	0.	4.123E-01	2.629E 00	8.842E-01	2.665E 00	3.951E-01	89.	-10.
530.	POS	5.195E 01	-0.	8.478E 01	9.595E 01	1.262E 02	1.580E 02	1.043E 01	271.	53.
	VEL	9.779E-01	0.	3.949E-01	3.147E 00	9.096E-01	3.178E 00	3.623E-01	88.	-8.
540.	POS	5.376E 01	-0.	8.415E 01	1.143E 02	1.339E 02	1.753E 02	1.042E 01	275.	49.
	VEL	1.023E 00	0.	4.018E-01	3.781E 00	9.338E-01	3.809E 00	3.336E-01	87.	-6.
550.	POS	5.713E 01	-0.	8.264E 01	1.437E 02	1.419E 02	1.983E 02	1.041E 01	278.	44.
	VEL	1.053E 00	0.	4.443E-01	4.477E 00	9.372E-01	4.506E 00	3.038E-01	86.	-5.
560.	POS	6.208E 01	-0.	8.005E 01	1.841E 02	1.500E 02	2.294E 02	1.039E 01	278.	37.
	VEL	1.090E 00	-0.	5.410E-01	5.331E 00	9.404E-01	5.364E 00	2.799E-01	85.	-4.

Figure 1.22 SUMMARY DATA FOR RUN NO. 25

RUN NO.= 26 LATE BERM

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.50000	33.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-55.50000	38.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-53.50000	29.00000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 01	1.0000000E 01	1.0000000E 01	1.7600428E 06	-2.4838150E 05	-7.3684625E 04
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.4090024E 06	-4.9852918E 05	-5.4811806E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.5094966E 06	-5.3338412E 05	4.6293119E 05

TIME	P,V	RHJ	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
530.	POS	5.736E 01	0.	1.237E 02	1.161E 02	1.323E 02	1.932E 02	1.038E 01	50.	-39.
	VEL	1.080E 00	0.	2.121E 00	4.051E 00	8.989E-01	4.569E 00	3.207E-01	63.	-4.
540.	POS	5.265E 01	0.	1.047E 02	9.430E 01	1.250E 02	1.686E 02	1.040E 01	52.	-46.
	VEL	1.075E 00	0.	1.890E 00	3.445E 00	9.225E-01	3.923E 00	3.604E-01	62.	-4.
550.	POS	4.939E 01	-0.	8.832E 01	8.374E 01	1.178E 02	1.506E 02	1.042E 01	55.	-51.
	VEL	1.050E 00	0.	1.649E 00	2.863E 00	9.258E-01	3.293E 00	4.004E-01	61.	-6.
560.	POS	4.765E 01	-0.	7.425E 01	8.233E 01	1.108E 02	1.368E 02	1.042E 01	60.	-54.
	VEL	1.031E 00	0.	1.445E 00	2.400E 00	9.293E-01	2.783E 00	4.492E-01	60.	-7.
570.	POS	4.697E 01	-0.	6.221E 01	8.634E 01	1.042E 02	1.258E 02	1.042E 01	66.	-54.
	VEL	1.017E 00	0.	1.270E 00	2.046E 00	9.327E-01	2.377E 00	5.068E-01	60.	-9.
580.	POS	4.682E 01	-0.	5.197E 01	9.270E 01	9.805E 01	1.171E 02	1.041E 01	74.	-51.
	VEL	1.008E 00	0.	1.118E 00	1.800E 00	9.362E-01	2.070E 00	5.683E-01	61.	-11.
590.	POS	4.685E 01	-0.	4.332E 01	9.972E 01	9.238E 01	1.111E 02	1.041E 01	84.	-41.
	VEL	1.004E 00	0.	9.859E-01	1.669E 00	9.398E-01	1.869E 00	6.181E-01	64.	-12.
600.	POS	4.690E 01	-0.	3.612E 01	1.068E 02	8.732E 01	1.100E 02	1.041E 01	92.	-20.
	VEL	1.004E 00	-0.	8.720E-01	1.656E 00	9.433E-01	1.786E 00	6.314E-01	69.	-12.
610.	POS	4.698E 01	-0.	3.023E 01	1.140E 02	8.301E 01	1.145E 02	1.041E 01	94.	-4.
	VEL	1.008E 00	-0.	7.783E-01	1.755E 00	9.469E-01	1.832E 00	6.038E-01	74.	-9.
620.	POS	4.717E 01	-0.	2.557E 01	1.218E 02	7.957E 01	1.221E 02	1.041E 01	273.	-3.
	VEL	1.017E 00	-0.	7.094E-01	1.948E 00	9.505E-01	1.999E 00	5.552E-01	77.	-6.
630.	POS	4.757E 01	-0.	2.215E 01	1.310E 02	7.715E 01	1.317E 02	1.042E 01	271.	-7.
	VEL	1.029E 00	-0.	6.736E-01	2.220E 00	9.540E-01	2.263E 00	5.030E-01	79.	-4.
640.	POS	4.835E 01	-0.	2.018E 01	1.427E 02	7.584E 01	1.441E 02	1.042E 01	89.	9.
	VEL	1.046E 00	-0.	6.805E-01	2.561E 00	9.576E-01	2.608E 00	4.554E-01	79.	-2.
650.	POS	4.968E 01	-0.	2.011E 01	1.580E 02	7.572E 01	1.600E 02	1.043E 01	88.	10.
	VEL	1.067E 00	-0.	7.372E-01	2.969E 00	9.611E-01	3.029E 00	4.149E-01	79.	-1.
660.	POS	5.169E 01	-0.	2.251E 01	1.781E 02	7.682E 01	1.806E 02	1.043E 01	86.	9.
	VEL	1.093E 00	-0.	8.462E-01	3.448E 00	9.647E-01	3.528E 00	3.815E-01	78.	-1.
670.	POS	5.448E 01	-0.	2.771E 01	2.040E 02	7.908E 01	2.072E 02	1.043E 01	84.	9.
	VEL	1.124E 00	-0.	1.007E 00	4.008E 00	9.682E-01	4.117E 00	3.545E-01	77.	-0.
680.	POS	5.807E 01	-0.	3.583E 01	2.370E 02	8.243E 01	2.410E 02	1.042E 01	82.	7.
	VEL	1.160E 00	-0.	1.221E 00	4.668E 00	9.717E-01	4.813E 00	3.326E-01	76.	-0.
690.	POS	6.241E 01	-0.	4.706E 01	2.782E 02	8.674E 01	2.833E 02	1.041E 01	81.	6.
	VEL	1.203E 00	-0.	1.493E 00	5.453E 00	9.753E-01	5.644E 00	3.151E-01	75.	-0.

Figure 1.23 SUMMARY DATA FOR RUN NO. 26

RUN NO.= 27 OFFSHORE FLA

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-79.50000	28.60000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-72.90000	35.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-70.60000	26.40000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	9.2970390E 04	-7.4825000E 02	2.9779000E 04
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	8.8267585E 05	-7.9955437E 04	-4.8299146E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	8.7010127E 05	-7.9302625E 04	4.9709765E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
220.	POS	1.746E 01	-0.	1.646E 01	3.626E 01	3.190E 01	3.959E 01	4.215E 00	294.	-1.
	VEL	1.317E-01	0.	9.390E-02	1.839E-01	1.397E-01	1.894E-01	8.888E-02	79.	15.
230.	POS	1.740E 01	-0.	1.577E 01	3.739E 01	3.095E 01	4.036E 01	4.216E 00	292.	-1.
	VEL	1.326E-01	0.	9.348E-02	1.802E-01	1.418E-01	1.836E-01	9.152E-02	83.	14.
240.	POS	1.731E 01	-0.	1.510E 01	3.838E 01	3.000E 01	4.103E 01	4.217E 00	291.	-1.
	VEL	1.342E-01	0.	9.331E-02	1.813E-01	1.441E-01	1.830E-01	9.280E-02	87.	12.
250.	POS	1.722E 01	-0.	1.445E 01	3.926E 01	2.906E 01	4.162E 01	4.219E 00	289.	-1.
	VEL	1.363E-01	0.	9.332E-02	1.863E-01	1.464E-01	1.873E-01	9.287E-02	271.	-9.
260.	POS	1.711E 01	-0.	1.382E 01	4.006E 01	2.814E 01	4.217E 01	4.220E 00	288.	-1.
	VEL	1.389E-01	0.	9.345E-02	1.950E-01	1.489E-01	1.958E-01	9.209E-02	274.	-5.
270.	POS	1.699E 01	-0.	1.322E 01	4.079E 01	2.723E 01	4.268E 01	4.222E 00	287.	-1.
	VEL	1.420E-01	0.	9.365E-02	2.069E-01	1.515E-01	2.081E-01	9.080E-02	277.	-3.
280.	POS	1.688E 01	-0.	1.265E 01	4.149E 01	2.636E 01	4.317E 01	4.225E 00	286.	-1.
	VEL	1.455E-01	0.	9.389E-02	2.220E-01	1.543E-01	2.238E-01	8.928E-02	278.	-1.
290.	POS	1.676E 01	-0.	1.210E 01	4.218E 01	2.551E 01	4.368E 01	4.227E 00	285.	-1.
	VEL	1.496E-01	0.	9.412E-02	2.403E-01	1.571E-01	2.426E-01	8.770E-02	279.	0.
300.	POS	1.666E 01	-0.	1.158E 01	4.290E 01	2.472E 01	4.424E 01	4.230E 00	284.	-1.
	VEL	1.540E-01	0.	9.431E-02	2.619E-01	1.601E-01	2.647E-01	8.616E-02	279.	1.
310.	POS	1.657E 01	-0.	1.110E 01	4.367E 01	2.397E 01	4.487E 01	4.232E 00	283.	-1.
	VEL	1.589E-01	0.	9.443E-02	2.872E-01	1.632E-01	2.902E-01	8.473E-02	279.	1.
320.	POS	1.650E 01	-0.	1.066E 01	4.454E 01	2.330E 01	4.561E 01	4.235E 00	282.	-2.
	VEL	1.643E-01	0.	9.446E-02	3.163E-01	1.665E-01	3.195E-01	8.343E-02	278.	1.
330.	POS	1.647E 01	-0.	1.025E 01	4.557E 01	2.270E 01	4.653E 01	4.237E 00	282.	-2.
	VEL	1.702E-01	0.	9.435E-02	3.498E-01	1.699E-01	3.529E-01	8.229E-02	278.	1.
340.	POS	1.648E 01	-0.	9.893E 00	4.681E 01	2.220E 01	4.768E 01	4.240E 00	281.	-2.
	VEL	1.766E-01	0.	9.409E-02	3.882E-01	1.734E-01	3.912E-01	8.132E-02	277.	1.
350.	POS	1.655E 01	-0.	9.578E 00	4.835E 01	2.181E 01	4.913E 01	4.241E 00	280.	-2.
	VEL	1.836E-01	0.	9.362E-02	4.321E-01	1.771E-01	4.348E-01	8.052E-02	276.	1.
360.	POS	1.669E 01	-0.	9.308E 00	5.026E 01	2.154E 01	5.097E 01	4.242E 00	279.	-2.
	VEL	1.913E-01	0.	9.293E-02	4.823E-01	1.810E-01	4.848E-01	7.990E-02	276.	1.
370.	POS	1.690E 01	-0.	9.080E 00	5.266E 01	2.141E 01	5.330E 01	4.243E 00	279.	-2.
	VEL	1.996E-01	0.	9.198E-02	5.399E-01	1.851E-01	5.420E-01	7.947E-02	275.	1.
380.	POS	1.721E 01	-0.	8.891E 00	5.566E 01	2.144E 01	5.623E 01	4.242E 00	278.	-2.
	VEL	2.088E-01	0.	9.075E-02	6.061E-01	1.894E-01	6.078E-01	7.922E-02	274.	1.
390.	POS	1.763E 01	-0.	8.732E 00	5.938E 01	2.163E 01	5.990E 01	4.240E 00	277.	-2.
	VEL	2.187E-01	0.	8.924E-02	6.823E-01	1.938E-01	6.836E-01	7.916E-02	273.	1.
400.	POS	1.816E 01	-0.	8.593E 00	6.398E 01	2.199E 01	6.443E 01	4.236E 00	277.	-2.
	VEL	2.297E-01	0.	8.748E-02	7.704E-01	1.985E-01	7.713E-01	7.931E-02	273.	1.
410.	POS	1.881E 01	-0.	8.462E 00	6.959E 01	2.253E 01	6.999E 01	4.233E 00	276.	-1.
	VEL	2.417E-01	0.	8.556E-02	8.726E-01	2.033E-01	8.733E-01	7.966E-02	272.	1.
420.	POS	1.960E 01	-0.	8.323E 00	7.641E 01	2.324E 01	7.676E 01	4.228E 00	275.	-1.
	VEL	2.549E-01	0.	8.371E-02	9.920E-01	2.084E-01	9.924E-01	8.023E-02	271.	1.
430.	POS	2.052E 01	-0.	8.155E 00	8.464E 01	2.412E 01	8.493E 01	4.223E 00	275.	-1.
	VEL	2.695E-01	0.	8.231E-02	1.132E 00	2.138E-01	1.132E 00	8.102E-02	271.	1.

Figure 1.24 SUMMARY DATA FOR RUN NO. 27

RUN NO.= 28 EARLY BERM

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-72.00000	35.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-69.70000	26.40000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-63.10000	33.00000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	9.6156968E 05	-9.0034499E 04	-4.6313540E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	9.5634693E 05	-9.3441937E 04	5.1701484E 05
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	1.7068307E 06	-2.3344556E 05	-8.2411875E 04

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
350.	POS	1.998E 01	0.	3.066E 01	7.687E 01	2.280E 01	8.265E 01	4.224E 00	68.	2.
	VEL	2.458E-01	-0.	2.987E-01	9.471E-01	1.779E-01	9.893E-01	8.372E-02	73.	1.
360.	POS	1.924E 01	0.	2.893E 01	6.989E 01	2.226E 01	7.550E 01	4.228E 00	68.	2.
	VEL	2.411E-01	-0.	2.835E-01	8.609E-01	1.816E-01	9.021E-01	8.477E-02	73.	1.
370.	POS	1.860E 01	0.	2.744E 01	6.384E 01	2.183E 01	6.933E 01	4.232E 00	67.	2.
	VEL	2.373E-01	-0.	2.702E-01	7.847E-01	1.855E-01	8.250E-01	8.635E-02	72.	0.
380.	POS	1.805E 01	0.	2.620E 01	5.863E 01	2.155E 01	6.404E 01	4.235E 00	66.	2.
	VEL	2.343E-01	-0.	2.582E-01	7.169E-01	1.895E-01	7.562E-01	8.856E-02	71.	0.
390.	POS	1.759E 01	0.	2.520E 01	5.417E 01	2.142E 01	5.953E 01	4.238E 00	65.	2.
	VEL	2.322E-01	-0.	2.475E-01	6.562E-01	1.938E-01	6.944E-01	9.150E-02	71.	-0.
400.	POS	1.724E 01	-0.	2.442E 01	5.036E 01	2.145E 01	5.571E 01	4.239E 00	65.	2.
	VEL	2.308E-01	0.	2.376E-01	6.016E-01	1.983E-01	6.386E-01	9.531E-02	70.	-1.
410.	POS	1.697E 01	-0.	2.386E 01	4.710E 01	2.167E 01	5.250E 01	4.240E 00	64.	2.
	VEL	2.302E-01	0.	2.284E-01	5.528E-01	2.030E-01	5.882E-01	1.001E-01	70.	-1.
420.	POS	1.680E 01	-0.	2.350E 01	4.429E 01	2.207E 01	4.979E 01	4.239E 00	63.	1.
	VEL	2.304E-01	0.	2.197E-01	5.096E-01	2.079E-01	5.430E-01	1.061E-01	69.	-2.
430.	POS	1.670E 01	-0.	2.333E 01	4.184E 01	2.267E 01	4.748E 01	4.238E 00	61.	1.
	VEL	2.315E-01	0.	2.113E-01	4.727E-01	2.130E-01	5.034E-01	1.135E-01	70.	-4.
440.	POS	1.667E 01	-0.	2.333E 01	3.963E 01	2.346E 01	4.548E 01	4.236E 00	60.	-0.
	VEL	2.335E-01	0.	2.031E-01	4.434E-01	2.185E-01	4.708E-01	1.222E-01	71.	-6.
450.	POS	1.669E 01	-0.	2.346E 01	3.756E 01	2.443E 01	4.368E 01	4.233E 00	59.	-2.
	VEL	2.365E-01	0.	1.949E-01	4.236E-01	2.241E-01	4.475E-01	1.323E-01	73.	-10.
460.	POS	1.674E 01	-0.	2.369E 01	3.556E 01	2.558E 01	4.203E 01	4.230E 00	58.	-4.
	VEL	2.404E-01	0.	1.864E-01	4.163E-01	2.300E-01	4.373E-01	1.430E-01	76.	-13.
470.	POS	1.681E 01	-0.	2.401E 01	3.354E 01	2.691E 01	4.048E 01	4.228E 00	57.	-9.
	VEL	2.454E-01	0.	1.777E-01	4.250E-01	2.362E-01	4.442E-01	1.529E-01	80.	-16.
480.	POS	1.687E 01	-0.	2.437E 01	3.150E 01	2.840E 01	3.913E 01	4.226E 00	56.	-16.
	VEL	2.516E-01	0.	1.686E-01	4.526E-01	2.427E-01	4.708E-01	1.589E-01	84.	-17.
490.	POS	1.692E 01	-0.	2.474E 01	2.947E 01	3.004E 01	3.836E 01	4.225E 00	59.	-28.
	VEL	2.590E-01	0.	1.590E-01	5.017E-01	2.496E-01	5.187E-01	1.569E-01	87.	-16.
500.	POS	1.695E 01	-0.	2.508E 01	2.766E 01	3.183E 01	3.883E 01	4.226E 00	66.	-42.
	VEL	2.678E-01	0.	1.492E-01	5.739E-01	2.567E-01	5.892E-01	1.481E-01	89.	-14.
510.	POS	1.698E 01	-0.	2.536E 01	2.648E 01	3.376E 01	4.071E 01	4.228E 00	75.	-51.
	VEL	2.781E-01	0.	1.394E-01	6.710E-01	2.642E-01	6.841E-01	1.370E-01	89.	-12.
520.	POS	1.705E 01	-0.	2.553E 01	2.666E 01	3.583E 01	4.368E 01	4.231E 00	84.	-54.
	VEL	2.901E-01	0.	1.309E-01	7.954E-01	2.720E-01	8.065E-01	1.263E-01	89.	-10.
530.	POS	1.730E 01	-0.	2.555E 01	2.913E 01	3.802E 01	4.765E 01	4.233E 00	271.	53.
	VEL	3.040E-01	0.	1.257E-01	9.514E-01	2.802E-01	9.608E-01	1.168E-01	88.	-8.
540.	POS	1.790E 01	-0.	2.536E 01	3.465E 01	4.034E 01	5.288E 01	4.230E 00	275.	49.
	VEL	3.195E-01	0.	1.275E-01	1.143E 00	2.882E-01	1.152E 00	1.088E-01	87.	-7.
550.	POS	1.902E 01	-0.	2.491E 01	4.351E 01	4.275E 01	5.984E 01	4.221E 00	278.	44.
	VEL	3.311E-01	0.	1.396E-01	1.355E 00	2.901E-01	1.364E 00	1.007E-01	86.	-5.
560.	POS	2.067E 01	-0.	2.412E 01	5.573E 01	4.521E 01	6.926E 01	4.209E 00	278.	37.
	VEL	3.455E-01	-0.	1.677E-01	1.616E 00	2.920E-01	1.626E 00	9.467E-02	85.	-4.

Figure 1.25 SUMMARY DATA FOR RUN NO. 28

RUN NO.= 29 LATE BERM

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.50000	33.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-55.50000	38.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-53.50000	29.00000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	1.7600428E 06	-2.4838150E 05	-7.3684625E 04
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.4090024E 06	-4.9852918E 05	-5.4811806E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.5094966E 06	-5.3338412E 05	4.6293119E 05

TIME	P,V	PHI	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
530.	POS	1.911E 01	0.	3.741E 01	3.535E 01	3.992E 01	5.844E 01	4.196E 00	50.	-38.
	VEL	3.393E-01	0.	6.472E-01	1.231E 00	2.796E-01	1.389E 00	1.053E-01	63.	-4.
540.	POS	1.754E 01	0.	3.169E 01	2.870E 01	3.770E 01	5.098E 01	4.212E 00	52.	-45.
	VEL	3.348E-01	0.	5.749E-01	1.045E 00	2.856E-01	1.190E 00	1.161E-01	62.	-5.
550.	POS	1.646E 01	-0.	2.673E 01	2.547E 01	3.553E 01	4.550E 01	4.225E 00	55.	-51.
	VEL	3.251E-01	0.	5.009E-01	8.673E-01	2.857E-01	9.977E-01	1.274E-01	61.	-6.
560.	POS	1.588E 01	-0.	2.250E 01	2.502E 01	3.344E 01	4.133E 01	4.229E 00	60.	-54.
	VEL	3.178E-01	0.	4.390E-01	7.272E-01	2.859E-01	8.431E-01	1.415E-01	60.	-7.
570.	POS	1.565E 01	-0.	1.890E 01	2.621E 01	3.145E 01	3.803E 01	4.227E 00	66.	-54.
	VEL	3.126E-01	0.	3.864E-01	6.208E-01	2.862E-01	7.210E-01	1.583E-01	60.	-9.
580.	POS	1.560E 01	-0.	1.585E 01	2.812E 01	2.959E 01	3.541E 01	4.222E 00	74.	-51.
	VEL	3.092E-01	0.	3.410E-01	5.473E-01	2.865E-01	6.292E-01	1.764E-01	61.	-11.
590.	POS	1.561E 01	-0.	1.331E 01	3.023E 01	2.788E 01	3.361E 01	4.219E 00	84.	-40.
	VEL	3.075E-01	0.	3.016E-01	5.082E-01	2.870E-01	5.688E-01	1.911E-01	64.	-12.
600.	POS	1.563E 01	-0.	1.122E 01	3.234E 01	2.635E 01	3.331E 01	4.218E 00	92.	-20.
	VEL	3.074E-01	-0.	2.679E-01	5.045E-01	2.875E-01	5.440E-01	1.951E-01	69.	-12.
610.	POS	1.566E 01	-0.	9.546E 00	3.449E 01	2.505E 01	3.465E 01	4.219E 00	94.	-5.
	VEL	3.089E-01	-0.	2.402E-01	5.340E-01	2.880E-01	5.577E-01	1.872E-01	74.	-9.
620.	POS	1.572E 01	-0.	8.252E 00	3.682E 01	2.401E 01	3.688E 01	4.222E 00	273.	-3.
	VEL	3.120E-01	-0.	2.200E-01	5.921E-01	2.886E-01	6.076E-01	1.734E-01	77.	-6.
630.	POS	1.585E 01	-0.	7.324E 00	3.957E 01	2.327E 01	3.978E 01	4.226E 00	271.	-7.
	VEL	3.166E-01	-0.	2.095E-01	6.741E-01	2.893E-01	6.871E-01	1.587E-01	79.	-4.
640.	POS	1.611E 01	-0.	6.792E 00	4.307E 01	2.288E 01	4.348E 01	4.231E 00	89.	9.
	VEL	3.230E-01	-0.	2.114E-01	7.773E-01	2.901E-01	7.914E-01	1.455E-01	79.	-2.
650.	POS	1.655E 01	-0.	6.754E 00	4.766E 01	2.284E 01	4.826E 01	4.235E 00	87.	10.
	VEL	3.310E-01	-0.	2.279E-01	9.010E-01	2.910E-01	9.188E-01	1.345E-01	79.	-1.
660.	POS	1.722E 01	-0.	7.363E 00	5.371E 01	2.316E 01	5.448E 01	4.236E 00	86.	9.
	VEL	3.409E-01	-0.	2.600E-01	1.047E 00	2.920E-01	1.071E 00	1.258E-01	78.	-1.
670.	POS	1.815E 01	-0.	8.764E 00	6.156E 01	2.384E 01	6.251E 01	4.234E 00	84.	9.
	VEL	3.529E-01	-0.	3.078E-01	1.218E 00	2.932E-01	1.250E 00	1.191E-01	77.	-0.
680.	POS	1.934E 01	-0.	1.106E 01	7.156E 01	2.485E 01	7.273E 01	4.230E 00	83.	7.
	VEL	3.671E-01	-0.	3.718E-01	1.420E 00	2.945E-01	1.463E 00	1.142E-01	76.	-0.
690.	POS	2.078E 01	-0.	1.432E 01	8.407E 01	2.615E 01	8.556E 01	4.223E 00	81.	6.
	VEL	3.839E-01	-0.	4.538E-01	1.661E 00	2.959E-01	1.718E 00	1.107E-01	75.	0.

Figure 1.26 SUMMARY DATA FOR RUN NO. 29

RUN NO.= 30 OFFSHORE

R	LONG.	LAT.	MIN EL.	DEL R	DEL ROOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-80.10000	28.60000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-79.60000	32.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-76.80000	26.70000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA ROOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	3.7159555E 04	-1.1987500E 02	1.2005156E 04
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	2.2428492E 05	-1.7689687E 04	-4.1807084E 05
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	2.8580067E 05	-1.3918937E 04	3.0899297E 05

TIME	P.V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
150.	POS	5.014E 00	-0.	5.248E 00	6.822E 00	3.344E 00	9.418E 00	3.177E 00	293.	-4.
	VEL	7.279E-02	0.	8.203E-02	1.376E-01	4.267E-02	1.477E-01	4.155E-02	293.	-3.
160.	POS	5.056E 00	-0.	5.390E 00	8.969E 00	3.315E 00	9.605E 00	3.142E 00	293.	-4.
	VEL	7.235E-02	0.	8.252E-02	1.440E-01	4.231E-02	1.553E-01	4.100E-02	294.	-3.
170.	POS	5.100E 00	-0.	5.585E 00	9.120E 00	3.298E 00	9.842E 00	3.119E 00	294.	-5.
	VEL	7.287E-02	0.	8.406E-02	1.527E-01	4.217E-02	1.649E-01	4.069E-02	294.	-3.
180.	POS	5.153E 00	-0.	5.829E 00	9.340E 00	3.296E 00	1.019E 01	3.110E 00	296.	-5.
	VEL	7.398E-02	0.	8.620E-02	1.631E-01	4.221E-02	1.760E-01	4.058E-02	293.	-3.
190.	POS	5.219E 00	-0.	6.115E 00	9.687E 00	3.307E 00	1.069E 01	3.115E 00	297.	-5.
	VEL	7.560E-02	0.	8.885E-02	1.755E-01	4.243E-02	1.889E-01	4.067E-02	293.	-3.
200.	POS	5.303E 00	-0.	6.437E 00	1.021E 01	3.334E 00	1.138E 01	3.136E 00	298.	-5.
	VEL	7.771E-02	0.	9.196E-02	1.903E-01	4.285E-02	2.041E-01	4.099E-02	292.	-3.
210.	POS	5.408E 00	-0.	6.790E 00	1.096E 01	3.375E 00	1.229E 01	3.175E 00	298.	-5.
	VEL	8.032E-02	0.	9.545E-02	2.078E-01	4.348E-02	2.220E-01	4.153E-02	291.	-3.
220.	POS	5.536E 00	-0.	7.169E 00	1.195E 01	3.433E 00	1.342E 01	3.232E 00	298.	-5.
	VEL	8.342E-02	0.	9.929E-02	2.283E-01	4.432E-02	2.428E-01	4.229E-02	290.	-2.
230.	POS	5.689E 00	-0.	7.570E 00	1.321E 01	3.506E 00	1.480E 01	3.307E 00	297.	-5.
	VEL	8.705E-02	0.	1.034E-01	2.521E-01	4.537E-02	2.668E-01	4.328E-02	289.	-2.
240.	POS	5.868E 00	-0.	7.989E 00	1.476E 01	3.596E 00	1.643E 01	3.400E 00	296.	-4.
	VEL	9.120E-02	0.	1.078E-01	2.795E-01	4.662E-02	2.943E-01	4.447E-02	288.	-2.
250.	POS	6.073E 00	-0.	8.423E 00	1.660E 01	3.701E 00	1.833E 01	3.468E 00	295.	-4.
	VEL	9.589E-02	0.	1.124E-01	3.109E-01	4.807E-02	3.255E-01	4.585E-02	287.	-2.
260.	POS	6.304E 00	-0.	8.870E 00	1.876E 01	3.821E 00	2.051E 01	3.352E 00	294.	-3.
	VEL	1.011E-01	0.	1.171E-01	3.464E-01	4.971E-02	3.609E-01	4.741E-02	286.	-2.
270.	POS	6.561E 00	-0.	9.325E 00	2.123E 01	3.957E 00	2.299E 01	3.241E 00	293.	-3.
	VEL	1.069E-01	0.	1.219E-01	3.866E-01	5.153E-02	4.008E-01	4.915E-02	285.	-1.
280.	POS	6.844E 00	-0.	9.786E 00	2.405E 01	4.108E 00	2.579E 01	3.144E 00	291.	-3.
	VEL	1.136E-01	0.	1.267E-01	4.318E-01	5.352E-02	4.457E-01	5.104E-02	284.	-1.
290.	POS	7.152E 00	-0.	1.025E 01	2.723E 01	4.273E 00	2.895E 01	3.059E 00	290.	-2.
	VEL	1.204E-01	0.	1.316E-01	4.825E-01	5.567E-02	4.960E-01	5.310E-02	283.	-1.
300.	POS	7.485E 00	-0.	1.071E 01	3.081E 01	4.452E 00	3.250E 01	2.985E 00	289.	-2.
	VEL	1.281E-01	0.	1.365E-01	5.395E-01	5.798E-02	5.525E-01	5.533E-02	283.	-1.
310.	POS	7.844E 00	-0.	1.118E 01	3.483E 01	4.644E 00	3.647E 01	2.922E 00	287.	-2.
	VEL	1.366E-01	0.	1.412E-01	6.035E-01	6.045E-02	6.159E-01	5.772E-02	282.	-1.
320.	POS	8.227E 00	-0.	1.163E 01	3.932E 01	4.850E 00	4.092E 01	2.866E 00	286.	-1.
	VEL	1.458E-01	0.	1.459E-01	6.754E-01	6.306E-02	6.871E-01	6.028E-02	281.	-1.
330.	POS	8.637E 00	-0.	1.208E 01	4.436E 01	5.069E 00	4.589E 01	2.818E 00	285.	-1.
	VEL	1.559E-01	0.	1.504E-01	7.563E-01	6.582E-02	7.673E-01	6.301E-02	280.	-1.
340.	POS	9.073E 00	-0.	1.251E 01	4.999E 01	5.301E 00	5.146E 01	2.777E 00	284.	-1.
	VEL	1.670E-01	0.	1.546E-01	8.474E-01	6.873E-02	8.577E-01	6.592E-02	279.	-0.
350.	POS	9.536E 00	-0.	1.291E 01	5.630E 01	5.545E 00	5.771E 01	2.741E 00	283.	-1.
	VEL	1.790E-01	0.	1.585E-01	9.505E-01	7.178E-02	9.600E-01	6.901E-02	278.	-0.
360.	POS	1.003E 01	-0.	1.330E 01	6.339E 01	5.802E 00	6.472E 01	2.710E 00	282.	-1.
	VEL	1.922E-01	0.	1.621E-01	1.067E 00	7.499E-02	1.076E 00	7.226E-02	277.	-0.
370.	POS	1.055E 01	-0.	1.365E 01	7.137E 01	6.071E 00	7.261E 01	2.682E 00	281.	-1.
	VEL	2.067E-01	0.	1.652E-01	1.201E 00	7.835E-02	1.208E 00	7.569E-02	276.	-0.
380.	POS	1.111E 01	-0.	1.396E 01	8.037E 01	6.353E 00	8.153E 01	2.658E 00	280.	-0.
	VEL	2.726E-01	0.	1.678E-01	1.353E 00	8.186E-02	1.360E 00	7.928E-02	276.	-0.
390.	POS	1.170E 01	-0.	1.421E 01	9.055E 01	6.647E 00	9.162E 01	2.637E 00	279.	-0.
	VEL	2.401E-01	0.	1.698E-01	1.528E 00	8.555E-02	1.534E 00	8.304E-02	275.	0.
400.	POS	1.233E 01	-0.	1.440E 01	1.021E 02	6.954E 00	1.031E 02	2.618E 00	278.	-0.
	VEL	2.595E-01	0.	1.712E-01	1.731E 00	8.943E-02	1.736E 00	8.695E-02	274.	0.
410.	POS	1.301E 01	-0.	1.450E 01	1.153E 02	7.274E 00	1.162E 02	2.602E 00	277.	-0.
	VEL	2.809E-01	0.	1.718E-01	1.968E 00	9.350E-02	1.972E 00	9.101E-02	274.	0.
420.	POS	1.373E 01	-0.	1.451E 01	1.305E 02	7.608E 00	1.313E 02	2.587E 00	276.	-0.
	VEL	3.048E-01	0.	1.718E-01	2.246E 00	9.781E-02	2.249E 00	9.523E-02	273.	0.

Figure 1.27 SUMMARY DATA FOR RUN NO. 30

RUN NO.= 31 OFFSHORE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-79.60000	28.60000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-74.60000	35.50000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-73.60000	24.10000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	8.3662804E 04	-6.0606250E 02	2.6836312E 04
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	7.4764596E 05	-7.0265812E 04	-5.7568468E 05
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	5.1624477E 05	-5.6621312E 04	6.7212431E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
220.	POS	4.848E 00	-0.	4.073E 00	8.489E 00	3.485E 00	8.596E 00	3.341E 00	280.	0.
	VEL	6.191E-02	0.	5.368E-02	1.096E-01	4.268E-02	1.110E-01	4.117E-02	280.	1.
230.	POS	4.874E 00	-0.	4.131E 00	8.611E 00	3.443E 00	8.716E 00	3.300E 00	280.	0.
	VEL	6.220E-02	0.	5.417E-02	1.121E-01	4.224E-02	1.137E-01	4.065E-02	281.	1.
240.	POS	4.902E 00	-0.	4.202E 00	8.722E 00	3.406E 00	8.830E 00	3.260E 00	280.	1.
	VEL	6.261E-02	0.	5.482E-02	1.150E-01	4.185E-02	1.168E-01	4.016E-02	281.	1.
250.	POS	4.931E 00	-0.	4.284E 00	8.833E 00	3.375E 00	8.949E 00	3.222E 00	280.	1.
	VEL	6.314E-02	0.	5.560E-02	1.184E-01	4.153E-02	1.203E-01	3.973E-02	281.	2.
260.	POS	4.963E 00	-0.	4.377E 00	8.955E 00	3.349E 00	9.087E 00	3.187E 00	281.	1.
	VEL	6.380E-02	0.	5.650E-02	1.224E-01	4.128E-02	1.246E-01	3.935E-02	282.	2.
270.	POS	5.000E 00	-0.	4.478E 00	9.102E 00	3.329E 00	9.258E 00	3.157E 00	282.	2.
	VEL	6.461E-02	0.	5.750E-02	1.272E-01	4.111E-02	1.297E-01	3.904E-02	282.	2.
280.	POS	5.043E 00	-0.	4.588E 00	9.288E 00	3.316E 00	9.478E 00	3.131E 00	283.	2.
	VEL	6.557E-02	0.	5.859E-02	1.330E-01	4.103E-02	1.357E-01	3.879E-02	282.	3.
290.	POS	5.093E 00	-0.	4.704E 00	9.529E 00	3.311E 00	9.763E 00	3.112E 00	284.	3.
	VEL	6.671E-02	0.	5.975E-02	1.399E-01	4.104E-02	1.430E-01	3.862E-02	283.	3.
300.	POS	5.151E 00	-0.	4.825E 00	9.845E 00	3.314E 00	1.013E 01	3.099E 00	285.	3.
	VEL	6.805E-02	0.	6.095E-02	1.483E-01	4.114E-02	1.517E-01	3.854E-02	283.	3.
310.	POS	5.718E 00	-0.	4.951E 00	1.026E 01	3.325E 00	1.060E 01	3.094E 00	286.	4.
	VEL	6.962E-02	0.	6.220E-02	1.584E-01	4.136E-02	1.621E-01	3.856E-02	283.	3.
320.	POS	5.797E 00	-0.	5.078E 00	1.078E 01	3.346E 00	1.119E 01	3.096E 00	286.	4.
	VEL	7.145E-02	0.	6.345E-02	1.704E-01	4.169E-02	1.743E-01	3.867E-02	282.	3.
330.	POS	5.388E 00	-0.	5.207E 00	1.144E 01	3.376E 00	1.191E 01	3.107E 00	287.	5.
	VEL	7.355E-02	0.	6.471E-02	1.847E-01	4.214E-02	1.887E-01	3.890E-02	282.	3.
340.	POS	5.492E 00	-0.	5.334E 00	1.226E 01	3.416E 00	1.279E 01	3.127E 00	287.	5.
	VEL	7.597E-02	0.	6.595E-02	2.014E-01	4.272E-02	2.055E-01	3.925E-02	281.	3.
350.	POS	5.612E 00	-0.	5.459E 00	1.327E 01	3.466E 00	1.384E 01	3.157E 00	287.	5.
	VEL	7.874E-02	0.	6.713E-02	2.209E-01	4.342E-02	2.250E-01	3.973E-02	281.	3.
360.	POS	5.748E 00	-0.	5.578E 00	1.447E 01	3.527E 00	1.508E 01	3.195E 00	286.	5.
	VEL	8.188E-02	0.	6.825E-02	2.435E-01	4.426E-02	2.475E-01	4.034E-02	280.	3.
370.	POS	5.903E 00	-0.	5.691E 00	1.591E 01	3.599E 00	1.653E 01	3.242E 00	286.	5.
	VEL	8.543E-02	0.	6.928E-02	2.698E-01	4.523E-02	2.736E-01	4.109E-02	279.	3.
380.	POS	6.076E 00	-0.	5.793E 00	1.759E 01	3.681E 00	1.821E 01	3.295E 00	285.	4.
	VEL	8.942E-02	0.	7.019E-02	3.000E-01	4.634E-02	3.036E-01	4.197E-02	278.	3.
390.	POS	6.271E 00	-0.	5.883E 00	1.955E 01	3.775E 00	2.016E 01	3.343E 00	284.	4.
	VEL	9.391E-02	0.	7.095E-02	3.348E-01	4.757E-02	3.380E-01	4.301E-02	278.	3.
400.	POS	6.488E 00	-0.	5.956E 00	2.183E 01	3.879E 00	2.242E 01	3.357E 00	283.	4.
	VEL	9.894E-02	0.	7.155E-02	3.747E-01	4.895E-02	3.776E-01	4.418E-02	277.	3.
410.	POS	6.728E 00	-0.	6.008E 00	2.445E 01	3.994E 00	2.500E 01	3.316E 00	282.	4.
	VEL	1.045E-01	0.	7.195E-02	4.207E-01	5.045E-02	4.232E-01	4.549E-02	276.	2.
420.	POS	6.994E 00	-0.	6.035E 00	2.746E 01	4.119E 00	2.798E 01	3.247E 00	281.	3.
	VEL	1.108E-01	0.	7.215E-02	4.736E-01	5.208E-02	4.757E-01	4.695E-02	275.	2.
430.	POS	7.286E 00	-0.	6.031E 00	3.092E 01	4.255E 00	3.139E 01	3.173E 00	279.	3.
	VEL	1.178E-01	0.	7.217E-02	5.346E-01	5.383E-02	5.363E-01	4.854E-02	274.	2.

Figure 1.28 SUMMARY DATA FOR RUN NO. 31

RUN NO.= 32 INTERMED

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-73.80000	35.50000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 0	-72.80000	24.10000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-63.10000	32.30000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	8.1728084E 05	-7.7243125E 04	-5.5705884E 05
3.0000000E 00	4.9999999E-02	3.0000000E 00	3.0000000E 00	3.0000000E 00	5.9437219E 05	-6.5680187E 04	6.9231622E 05
3.0000000E 00	4.9999999E-02	1.0000000E 01	1.0000000E 01	1.0000000E 01	1.6950654E 06	-2.2963525E 05	-5.5645937E 03

TIME	P.V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
350.	POS	6.888E 00	0.	1.052E 01	9.705E 00	3.716E 00	1.075E 01	3.148E 00	348.	11.
	VEL	7.984E-02	0.	9.674E-02	2.234E-01	4.322E-02	2.379E-01	3.874E-02	70.	3.
360.	POS	6.788E 00	-0.	9.846E 00	1.007E 01	3.676E 00	1.103E 01	3.169E 00	314.	9.
	VEL	7.820E-02	0.	9.342E-02	2.064E-01	4.334E-02	2.204E-01	3.908E-02	69.	3.
370.	POS	6.704E 00	-0.	9.191E 00	1.066E 01	3.650E 00	1.167E 01	3.202E 00	303.	8.
	VEL	7.681E-02	0.	9.041E-02	1.910E-01	4.362E-02	2.046E-01	3.956E-02	68.	3.
380.	POS	6.635E 00	-0.	8.560E 00	1.138E 01	3.640E 00	1.234E 01	3.246E 00	298.	7.
	VEL	7.566E-02	0.	8.765E-02	1.771E-01	4.408E-02	1.901E-01	4.017E-02	68.	3.
390.	POS	6.580E 00	-0.	7.953E 00	1.214E 01	3.647E 00	1.300E 01	3.303E 00	294.	6.
	VEL	7.472E-02	0.	8.512E-02	1.643E-01	4.471E-02	1.768E-01	4.094E-02	67.	3.
400.	POS	6.538E 00	-0.	7.371E 00	1.289E 01	3.670E 00	1.362E 01	3.373E 00	290.	5.
	VEL	7.401E-02	0.	8.277E-02	1.527E-01	4.553E-02	1.643E-01	4.187E-02	67.	3.
410.	POS	6.507E 00	-0.	6.817E 00	1.357E 01	3.712E 00	1.417E 01	3.457E 00	288.	5.
	VEL	7.352E-02	0.	8.058E-02	1.421E-01	4.654E-02	1.527E-01	4.296E-02	67.	2.
420.	POS	6.484E 00	-0.	6.294E 00	1.416E 01	3.771E 00	1.464E 01	3.553E 00	285.	5.
	VEL	7.327E-02	0.	7.849E-02	1.326E-01	4.773E-02	1.419E-01	4.424E-02	67.	2.
430.	POS	6.467E 00	-0.	5.806E 00	1.464E 01	3.848E 00	1.501E 01	3.664E 00	283.	4.
	VEL	7.330E-02	0.	7.648E-02	1.246E-01	4.910E-02	1.321E-01	4.572E-02	68.	1.
440.	POS	6.453E 00	-0.	5.358E 00	1.499E 01	3.944E 00	1.526E 01	3.787E 00	281.	4.
	VEL	7.367E-02	0.	7.448E-02	1.188E-01	5.064E-02	1.238E-01	4.741E-02	71.	-0.
450.	POS	6.438E 00	-0.	4.955E 00	1.518E 01	4.058E 00	1.537E 01	3.923E 00	279.	4.
	VEL	7.444E-02	0.	7.245E-02	1.160E-01	5.236E-02	1.185E-01	4.931E-02	76.	-2.
460.	POS	6.419E 00	-0.	4.604E 00	1.519E 01	4.189E 00	1.533E 01	4.063E 00	277.	4.
	VEL	7.572E-02	0.	7.032E-02	1.178E-01	5.425E-02	1.185E-01	5.141E-02	84.	-4.
470.	POS	6.391E 00	-0.	4.308E 00	1.502E 01	4.339E 00	1.511E 01	4.059E 00	276.	3.
	VEL	7.762E-02	0.	6.803E-02	1.255E-01	5.630E-02	1.260E-01	5.369E-02	272.	6.
480.	POS	6.351E 00	-0.	4.071E 00	1.465E 01	4.505E 00	1.471E 01	3.936E 00	274.	3.
	VEL	8.025E-02	0.	6.551E-02	1.405E-01	5.850E-02	1.417E-01	5.609E-02	276.	6.

Figure 1.29 SUMMARY DATA FOR RUN NO. 32

RUN NO.= 33 βER + 2S

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.50000	32.30000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-58.10000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-58.10000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 01	1.0000000E 01	1.0000000E 01	1.7486957E 06	-2.4468862E 05	3.2312188E 03
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.1856923E 06	-4.0195812E 05	-4.2769984E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.0778890E 06	-3.7396881E 05	5.5464659E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
480.	POS	4.019E 01	0.	1.049E 02	1.449E 02	3.822E 01	1.787E 02	9.503E 00	54.	-1.
	VEL	5.317E-01	-0.	1.738E 00	3.800E 00	2.511E-01	4.177E 00	1.445E-01	65.	1.
490.	POS	3.661E 01	0.	8.935E 01	1.107E 02	3.626E 01	1.419E 02	9.536E 00	51.	-2.
	VEL	5.158E-01	0.	1.521E 00	3.205E 00	2.550E-01	3.544E 00	1.520E-01	65.	1.
500.	POS	3.317E 01	0.	7.579E 01	8.189E 01	3.431E 01	1.112E 02	9.581E 00	47.	-3.
	VEL	5.038E-01	0.	1.339E 00	2.705E 00	2.597E-01	3.013E 00	1.627E-01	64.	0.
510.	POS	2.988E 01	0.	6.397E 01	5.781E 01	3.238E 01	8.572E 01	9.644E 00	42.	-4.
	VEL	4.952E-01	0.	1.183E 00	2.279E 00	2.651E-01	2.561E 00	1.772E-01	63.	0.
520.	POS	2.680E 01	0.	5.367E 01	3.799E 01	3.048E 01	6.508E 01	9.737E 00	35.	-7.
	VEL	4.894E-01	0.	1.047E 00	1.912E 00	2.710E-01	2.170E 00	1.964E-01	62.	0.
530.	POS	2.404E 01	0.	4.475E 01	2.258E 01	2.864E 01	4.915E 01	9.877E 00	25.	-10.
	VEL	4.863E-01	0.	9.264E-01	1.595E 00	2.776E-01	1.830E 00	2.212E-01	60.	-0.
540.	POS	2.185E 01	0.	3.710E 01	1.384E 01	2.689E 01	3.805E 01	1.007E 01	10.	-15.
	VEL	4.844E-01	0.	8.155E-01	1.323E 00	2.840E-01	1.531E 00	2.501E-01	59.	-0.
550.	POS	2.055E 01	-0.	3.073E 01	1.564E 01	2.530E 01	3.202E 01	1.026E 01	348.	-14.
	VEL	4.747E-01	0.	7.019E-01	1.086E 00	2.846E-01	1.258E 00	2.696E-01	59.	-1.
560.	POS	2.017E 01	-0.	2.557E 01	2.243E 01	2.393E 01	3.139E 01	1.036E 01	320.	0.
	VEL	4.681E-01	0.	6.050E-01	9.312E-01	2.853E-01	1.056E 00	2.779E-01	60.	-2.
570.	POS	2.040E 01	-0.	2.147E 01	2.962E 01	2.281E 01	3.450E 01	1.039E 01	303.	3.
	VEL	4.641E-01	0.	5.215E-01	8.627E-01	2.861E-01	9.351E-01	2.812E-01	65.	-3.
580.	POS	2.096E 01	-0.	1.829E 01	3.657E 01	2.200E 01	3.924E 01	1.041E 01	292.	3.
	VEL	4.626E-01	0.	4.497E-01	8.811E-01	2.870E-01	9.133E-01	2.829E-01	73.	-3.
590.	POS	2.173E 01	-0.	1.585E 01	4.360E 01	2.153E 01	4.505E 01	1.043E 01	285.	3.
	VEL	4.634E-01	0.	3.906E-01	9.736E-01	2.880E-01	9.883E-01	2.835E-01	80.	3.
600.	POS	2.271E 01	-0.	1.397E 01	5.125E 01	2.142E 01	5.202E 01	1.042E 01	280.	2.
	VEL	4.665E-01	0.	3.478E-01	1.122E 00	2.891E-01	1.132E 00	2.813E-01	82.	-2.
610.	POS	2.393E 01	-0.	1.247E 01	6.015E 01	2.170E 01	6.052E 01	1.039E 01	276.	2.
	VEL	4.720E-01	0.	3.275E-01	1.311E 00	2.904E-01	1.323E 00	2.662E-01	82.	-1.
620.	POS	2.541E 01	-0.	1.129E 01	7.089E 01	2.235E 01	7.103E 01	1.033E 01	273.	2.
	VEL	4.799E-01	-0.	3.363E-01	1.536E 00	2.918E-01	1.553E 00	2.409E-01	81.	-1.
630.	POS	2.718E 01	-0.	1.057E 01	8.401E 01	2.335E 01	8.407E 01	1.025E 01	271.	2.
	VEL	4.903E-01	-0.	3.772E-01	1.795E 00	2.933E-01	1.820E 00	2.189E-01	80.	-1.
640.	POS	2.923E 01	-0.	1.081E 01	1.000E 02	2.465E 01	1.001E 02	1.016E 01	88.	-2.
	VEL	5.035E-01	-0.	4.485E-01	2.091E 00	2.950E-01	2.128E 00	2.020E-01	79.	-0.
650.	POS	3.156E 01	-0.	1.266E 01	1.194E 02	2.622E 01	1.196E 02	1.006E 01	86.	-2.
	VEL	5.197E-01	-0.	5.478E-01	2.430E 00	2.968E-01	2.483E 00	1.894E-01	78.	-0.
660.	POS	3.415E 01	-0.	1.652E 01	1.426E 02	2.801E 01	1.432E 02	9.972E 00	85.	-1.
	VEL	5.393E-01	-0.	6.743E-01	2.822E 00	2.988E-01	2.896E 00	1.804E-01	77.	-0.
670.	POS	3.701E 01	-0.	2.247E 01	1.703E 02	2.999E 01	1.715E 02	9.890E 00	83.	-1.
	VEL	5.625E-01	-0.	8.302E-01	3.281E 00	3.009E-01	3.380E 00	1.743E-01	76.	0.
680.	POS	4.011E 01	0.	3.056E 01	2.031E 02	3.213E 01	2.052E 02	9.817E 00	82.	-1.
	VEL	5.900E-01	-0.	1.021E 00	3.825E 00	3.032E-01	3.955E 00	1.708E-01	75.	0.
690.	POS	4.347E 01	0.	4.102E 01	2.421E 02	3.440E 01	2.454E 02	9.753E 00	81.	-1.
	VEL	6.224E-01	-0.	1.254E 00	4.478E 00	3.058E-01	4.647E 00	1.694E-01	74.	0.

Figure 1.30 SUMMARY DATA FOR RUN NO. 33

RUN NO.= 34 BER + 2S

R	LONG.	LAT.	MIN EL.	DEL R	DEL ROOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.50000	32.30000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-58.10000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-58.10000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA ROOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 01	1.0000000E 01	1.0000000E 01	1.7486957E 06	-2.4468862E 05	3.2312188E 03
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.1856923E 06	-4.0195812E 05	-4.2769984E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.0778890E 06	-3.7396881E 05	5.5464659E 05

TIME	P.V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
480.	POS	8.871E 01	0.	3.252E 02	4.310E 02	1.252E 02	5.399E 02	1.034E 01	53.	-2.
	VEL	1.592E 00	-0.	5.163E 00	1.136E 01	7.942E-01	1.247E 01	4.085E-01	66.	0.
490.	POS	8.077E 01	0.	2.782E 02	3.279E 02	1.187E 02	4.299E 02	1.035E 01	50.	-2.
	VEL	1.563E 00	0.	4.522E 00	9.596E 00	8.119E-01	1.060E 01	4.426E-01	65.	0.
500.	POS	7.315E 01	0.	2.372E 02	2.409E 02	1.123E 02	3.380E 02	1.035E 01	46.	-4.
	VEL	1.542E 00	0.	3.986E 00	8.119E 00	8.317E-01	9.031E 00	4.851E-01	64.	0.
510.	POS	6.588E 01	0.	2.012E 02	1.676E 02	1.059E 02	2.619E 02	1.036E 01	40.	-5.
	VEL	1.528E 00	0.	3.528E 00	6.863E 00	8.532E-01	7.697E 00	5.383E-01	63.	0.
520.	POS	5.906E 01	0.	1.696E 02	1.066E 02	9.966E 01	2.003E 02	1.037E 01	32.	-8.
	VEL	1.521E 00	0.	3.129E 00	5.786E 00	8.764E-01	6.549E 00	6.052E-01	62.	-0.
530.	POS	5.297E 01	0.	1.420E 02	5.790E 01	9.361E 01	1.531E 02	1.039E 01	21.	-12.
	VEL	1.519E 00	0.	2.776E 00	4.863E 00	9.011E-01	5.554E 00	6.889E-01	61.	-0.
540.	POS	4.813E 01	0.	1.178E 02	3.043E 01	8.788E 01	1.204E 02	1.041E 01	6.	-17.
	VEL	1.520E 00	0.	2.452E 00	4.076E 00	9.251E-01	4.686E 00	7.883E-01	60.	-1.
550.	POS	4.527E 01	-0.	9.710E 01	4.391E 01	8.267E 01	1.032E 02	1.042E 01	344.	-13.
	VEL	1.493E 00	0.	2.117E 00	3.396E 00	9.289E-01	3.893E 00	8.683E-01	60.	-1.
560.	POS	4.442E 01	-0.	7.956E 01	6.993E 01	7.819E 01	1.025E 02	1.043E 01	319.	0.
	VEL	1.474E 00	0.	1.829E 00	2.959E 00	9.328E-01	3.319E 00	9.079E-01	62.	-2.
570.	POS	4.494E 01	-0.	6.470E 01	9.507E 01	7.457E 01	1.128E 02	1.044E 01	303.	4.
	VEL	1.463E 00	0.	1.582E 00	2.777E 00	9.368E-01	2.992E 00	9.215E-01	66.	-3.
580.	POS	4.621E 01	-0.	5.205E 01	1.189E 02	7.198E 01	1.285E 02	1.044E 01	292.	3.
	VEL	1.458E 00	0.	1.372E 00	2.841E 00	9.407E-01	2.949E 00	9.265E-01	73.	-3.
590.	POS	4.796E 01	-0.	4.116E 01	1.428E 02	7.053E 01	1.477E 02	1.044E 01	285.	3.
	VEL	1.459E 00	0.	1.203E 00	3.115E 00	9.447E-01	3.173E 00	9.229E-01	79.	-3.
600.	POS	5.020E 01	-0.	3.157E 01	1.684E 02	7.032E 01	1.708E 02	1.044E 01	279.	3.
	VEL	1.466E 00	0.	1.087E 00	3.548E 00	9.487E-01	3.592E 00	8.878E-01	81.	-2.
610.	POS	5.296E 01	-0.	2.301E 01	1.976E 02	7.137E 01	1.985E 02	1.044E 01	275.	2.
	VEL	1.480E 00	0.	1.039E 00	4.103E 00	9.527E-01	4.152E 00	8.050E-01	81.	-1.
620.	POS	5.633E 01	-0.	1.602E 01	2.320E 02	7.365E 01	2.322E 02	1.043E 01	272.	2.
	VEL	1.499E 00	-0.	1.078E 00	4.763E 00	9.568E-01	4.827E 00	7.212E-01	81.	-1.
630.	POS	6.032E 01	-0.	1.408E 01	2.732E 02	7.706E 01	2.734E 02	1.042E 01	89.	-2.
	VEL	1.525E 00	-0.	1.208E 00	5.524E 00	9.609E-01	5.615E 00	6.511E-01	80.	-1.
640.	POS	6.494E 01	-0.	2.108E 01	3.228E 02	8.146E 01	3.233E 02	1.041E 01	87.	-2.
	VEL	1.557E 00	-0.	1.425E 00	6.395E 00	9.650E-01	6.523E 00	5.947E-01	79.	-0.
650.	POS	7.016E 01	-0.	3.427E 01	3.821E 02	8.673E 01	3.836E 02	1.040E 01	85.	-2.
	VEL	1.596E 00	-0.	1.722E 00	7.395E 00	9.693E-01	7.572E 00	5.497E-01	78.	-0.
660.	POS	7.596E 01	-0.	5.188E 01	4.529E 02	9.273E 01	4.558E 02	1.040E 01	84.	-1.
	VEL	1.642E 00	-0.	2.100E 00	8.551E 00	9.737E-01	8.790E 00	5.139E-01	77.	0.
670.	POS	8.232E 01	-0.	7.401E 01	5.368E 02	9.933E 01	5.418E 02	1.039E 01	82.	-1.
	VEL	1.696E 00	-0.	2.566E 00	9.905E 00	9.784E-01	1.022E 01	4.855E-01	76.	0.
680.	POS	8.923E 01	0.	1.014E 02	6.361E 02	1.064E 02	6.441E 02	1.038E 01	81.	-1.
	VEL	1.759E 00	-0.	3.133E 00	1.151E 01	9.835E-01	1.192E 01	4.630E-01	75.	0.
690.	POS	9.670E 01	0.	1.351E 02	7.536E 02	1.140E 02	7.655E 02	1.037E 01	80.	-1.
	VEL	1.833E 00	-0.	3.827E 00	1.343E 01	9.893E-01	1.396E 01	4.454E-01	74.	0.

Figure 1.31 SUMMARY DATA FOR RUN NO. 34

RUN NO.= 35 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-57.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-57.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.1238564E 06	-3.9059725E 05	5.6004959E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	3.134E 01	-0.	2.916E 01	4.917E 01	2.662E 01	5.278E 01	2.181E 01	66.	1.
	VEL	2.803E-01	0.	4.030E-01	4.781E-01	3.022E-01	6.167E-01	1.208E-01	51.	9.
670.	POS	3.176E 01	-0.	2.892E 01	5.005E 01	2.846E 01	5.386E 01	2.079E 01	66.	1.
	VEL	2.755E-01	0.	3.548E-01	4.013E-01	3.041E-01	5.247E-01	1.362E-01	50.	14.
680.	POS	3.218E 01	-0.	2.901E 01	5.043E 01	3.050E 01	5.459E 01	1.993E 01	66.	2.
	VEL	2.719E-01	0.	3.101E-01	3.482E-01	3.062E-01	4.547E-01	1.563E-01	52.	22.
690.	POS	3.255E 01	-0.	2.926E 01	5.020E 01	3.271E 01	5.481E 01	1.919E 01	65.	4.
	VEL	2.696E-01	-0.	2.684E-01	3.258E-01	3.084E-01	4.156E-01	1.811E-01	58.	33.
700.	POS	3.282E 01	-0.	2.955E 01	4.931E 01	3.505E 01	5.446E 01	1.857E 01	64.	7.
	VEL	2.688E-01	-0.	2.300E-01	3.394E-01	3.107E-01	4.112E-01	2.012E-01	69.	37.

Figure 1.32 SUMMARY DATA FOR RUN NO. 35

RUN NO.= 36 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-57.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-57.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.7000C	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.1238564E 06	-3.9059725E 05	5.6004959E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P.V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	1.029E 02	-0.	9.657E 01	1.609E 02	8.825E 01	1.736E 02	7.073E 01	66.	1.
	VEL	8.832E-01	0.	1.300E 00	1.513E 00	9.872E-01	1.973E 00	3.623E-01	50.	9.
670.	POS	1.042E 02	-0.	9.590E 01	1.634E 02	9.442E 01	1.768E 02	6.743E 01	66.	1.
	VEL	8.706E-01	0.	1.140E 00	1.256E 00	9.913E-01	1.669E 00	4.164E-01	49.	15.
680.	POS	1.055E 02	-0.	9.625E 01	1.642E 02	1.012E 02	1.788E 02	6.460E 01	65.	3.
	VEL	8.611E-01	0.	9.909E-01	1.080E 00	9.956E-01	1.441E 00	4.877E-01	51.	25.
690.	POS	1.066E 02	-0.	9.709E 01	1.630E 02	1.085E 02	1.791E 02	6.215E 01	64.	4.
	VEL	8.548E-01	-0.	8.510E-01	1.011E 00	1.000E 00	1.320E 00	5.775E-01	59.	36.
700.	POS	1.073E 02	-0.	9.800E 01	1.596E 02	1.163E 02	1.776E 02	6.000E 01	63.	7.
	VEL	8.517E-01	-0.	7.214E-01	1.069E 00	1.005E 00	1.314E 00	6.499E-01	70.	39.

Figure 1.33 SUMMARY DATA FOR RUN NO. 36

RUN NO.= 37 BER BASE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.62000	32.30000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.
6.3709999E 06	-62.77000	32.38000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.
6.3709999E 06	-62.85000	32.33000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E-02	3.0000000E-02	3.0000000E-02	1.7379767E 06	-2.4163843E 05	1.4970312E 03
3.0000000E 00	4.9999999E-02	3.0000000E-02	3.0000000E-02	3.0000000E-02	1.7259042E 06	-2.3823537E 05	-9.4754375E 03
3.0000000E 00	4.9999999E-02	3.0000000E-02	3.0000000E-02	3.0000000E-02	1.7179239E 06	-2.3598987E 05	-5.1565937E 03

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
360.	POS	1.205E 02	1.500E 01	1.032E 03	2.665E 03	5.168E 02	2.883E 03	1.730E 00	69.	-8.
	VEL	9.874E 00	-2.174E-05	2.161E 01	6.141E 01	8.858E 00	6.530E 01	2.139E 00	71.	-5.
370.	POS	1.128E 02	1.500E 01	9.114E 02	2.277E 03	4.959E 02	2.480E 03	1.734E 00	68.	-9.
	VEL	8.967E 00	1.160E-05	1.885E 01	5.195E 01	8.533E 00	5.550E 01	1.990E 00	70.	-6.
380.	POS	1.055E 02	1.500E 01	8.075E 02	1.950E 03	4.744E 02	2.140E 03	1.731E 00	68.	-10.
	VEL	8.172E 00	-5.931E-05	1.658E 01	4.432E 01	8.200E 00	4.759E 01	1.853E 00	70.	-7.
390.	POS	9.869E 01	1.500E 01	7.168E 02	1.671E 03	4.524E 02	1.849E 03	1.732E 00	67.	-11.
	VEL	7.464E 00	-4.595E-05	1.467E 01	3.803E 01	7.863E 00	4.106E 01	1.728E 00	69.	-7.
400.	POS	9.216E 01	1.500E 01	6.364E 02	1.430E 03	4.298E 02	1.598E 03	1.734E 00	66.	-12.
	VEL	6.828E 00	-2.029E-05	1.304E 01	3.276E 01	7.519E 00	3.559E 01	1.615E 00	68.	-8.
410.	POS	8.585E 01	1.500E 01	5.645E 02	1.219E 03	4.067E 02	1.379E 03	1.732E 00	65.	-13.
	VEL	6.249E 00	-5.882E-05	1.162E 01	2.828E 01	7.171E 00	3.093E 01	1.510E 00	68.	-9.
420.	POS	7.968E 01	1.500E 01	4.996E 02	1.035E 03	3.830E 02	1.186E 03	1.731E 00	64.	-15.
	VEL	5.718E 00	-1.565E-05	1.037E 01	2.443E 01	6.818E 00	2.692E 01	1.414E 00	67.	-10.
430.	POS	7.370E 01	1.500E 01	4.406E 02	8.728E 02	3.588E 02	1.016E 03	1.733E 00	63.	-16.
	VEL	5.227E 00	-1.444E-05	9.260E 00	2.109E 01	6.462E 00	2.344E 01	1.324E 00	66.	-11.
440.	POS	6.782E 01	1.500E 01	3.865E 02	7.293E 02	3.340E 02	8.658E 02	1.732E 00	62.	-18.
	VEL	4.769E 00	-8.248E-06	8.262E 00	1.817E 01	6.103E 00	2.039E 01	1.238E 00	66.	-13.
450.	POS	6.204E 01	1.500E 01	3.369E 02	6.025E 02	3.087E 02	7.324E 02	1.732E 00	61.	-20.
	VEL	4.339E 00	-1.460E-06	7.360E 00	1.560E 01	5.743E 00	1.770E 01	1.156E 00	65.	-14.
460.	POS	5.636E 01	1.500E 01	2.913E 02	4.906E 02	2.830E 02	6.143E 02	1.733E 00	60.	-23.
	VEL	3.933E 00	-2.417E-06	6.540E 00	1.333E 01	5.382E 00	1.532E 01	1.077E 00	64.	-15.
470.	POS	5.074E 01	1.500E 01	2.492E 02	3.923E 02	2.569E 02	5.101E 02	1.732E 00	58.	-26.
	VEL	3.547E 00	1.014E-05	5.789E 00	1.131E 01	5.022E 00	1.320E 01	9.991E-01	63.	-17.
480.	POS	4.521E 01	1.500E 01	2.106E 02	3.067E 02	2.306E 02	4.187E 02	1.732E 00	56.	-29.
	VEL	3.179E 00	-3.194E-06	5.097E 00	9.500E 00	4.661E 00	1.130E 01	9.228E-01	62.	-19.
490.	POS	3.979E 01	1.500E 01	1.754E 02	2.330E 02	2.042E 02	3.395E 02	1.732E 00	54.	-33.
	VEL	2.825E 00	-1.728E-06	4.451E 00	7.871E 00	4.297E 00	9.582E 00	8.485E-01	61.	-21.
500.	POS	3.454E 01	1.500E 01	1.436E 02	1.708E 02	1.783E 02	2.719E 02	1.732E 00	51.	-37.
	VEL	2.486E 00	2.144E-06	3.837E 00	6.390E 00	3.918E 00	8.015E 00	7.787E-01	59.	-24.
510.	POS	2.958E 01	1.500E 01	1.155E 02	1.200E 02	1.535E 02	2.156E 02	1.733E 00	48.	-42.
	VEL	2.159E 00	3.228E-07	3.232E 00	5.036E 00	3.500E 00	6.557E 00	7.191E-01	58.	-27.
520.	POS	2.515E 01	1.500E 01	9.194E 01	8.039E 01	1.311E 02	1.709E 02	1.733E 00	44.	-48.
	VEL	1.847E 00	-2.041E-06	2.606E 00	3.807E 00	2.998E 00	5.157E 00	6.817E-01	56.	-30.
530.	POS	2.164E 01	1.500E 01	7.386E 01	5.177E 01	1.134E 02	1.386E 02	1.734E 00	39.	-53.
	VEL	1.559E 00	2.756E-07	1.933E 00	2.757E 00	2.368E 00	3.781E 00	6.762E-01	55.	-32.
540.	POS	1.971E 01	1.500E 01	6.261E 01	3.378E 01	1.039E 02	1.204E 02	1.734E 00	31.	-59.
	VEL	1.340E 00	-4.114E-08	1.290E 00	2.071E 00	1.784E 00	2.553E 00	6.330E-01	58.	-32.
550.	POS	1.995E 01	1.500E 01	5.862E 01	2.777E 01	1.056E 02	1.177E 02	1.734E 00	20.	-63.
	VEL	1.366E 00	1.059E-07	9.863E-01	2.021E 00	1.923E 00	2.131E 00	6.106E-01	289.	-47.
560.	POS	2.735E 01	1.500E 01	5.990E 01	3.793E 01	1.185E 02	1.287E 02	1.733E 00	3.	-66.
	VEL	1.652E 00	1.087E-06	1.044E 00	2.689E 00	2.646E 00	3.170E 00	6.453E-01	289.	-44.
570.	POS	2.640E 01	1.500E 01	6.331E 01	6.417E 01	1.397E 02	1.506E 02	1.733E 00	341.	-67.
	VEL	2.023E 00	2.145E-06	1.123E 00	3.849E 00	3.364E 00	4.391E 00	6.824E-01	283.	-36.
580.	POS	3.155E 01	1.500E 01	6.630E 01	1.053E 02	1.663E 02	1.823E 02	1.732E 00	317.	-62.
	VEL	2.437E 00	1.007E-06	1.146E 00	5.356E 00	3.972E 00	5.851E 00	7.462E-01	277.	-28.
590.	POS	3.745E 01	1.500E 01	6.712E 01	1.623E 02	1.961E 02	2.268E 02	1.732E 00	299.	-53.

Figure 1.34 SUMMARY DATA FOR RUN NO. 37 (Sheet 1)

	VEL	2.890E 00	-0.	1.166E 00	7.189E 00	4.513E 00	7.631E 00	8.310E-01	273.	-23.
600.	POS	4.391E 01	1.500E 01	6.464E 01	2.370E 02	2.282E 02	2.897E 02	1.732E 00	287.	-42.
	VEL	3.388E 00	3.498E-06	1.265E 00	9.390E 00	5.028E 00	9.798E 00	9.304E-01	90.	18.
610.	POS	5.085E 01	1.500E 01	5.809E 01	3.320E 02	2.618E 02	3.760E 02	1.732E 00	280.	-32.
	VEL	3.939E 00	6.790E-08	1.526E 00	1.205E 01	5.542E 00	1.244E 01	1.042E 00	87.	15.
620.	POS	5.824E 01	1.500E 01	4.746E 01	4.510E 02	2.964E 02	4.890E 02	1.732E 00	275.	-26.
	VEL	4.554E 00	1.893E-06	2.009E 00	1.528E 01	6.064E 00	1.569E 01	1.164E 00	85.	13.
630.	POS	6.611E 01	1.500E 01	3.611E 01	5.988E 02	3.320E 02	6.330E 02	1.732E 00	272.	-21.
	VEL	5.245E 00	1.183E-06	2.757E 00	1.926E 01	6.598E 00	1.971E 01	1.299E 00	84.	11.
640.	POS	7.451E 01	1.500E 01	4.019E 01	7.821E 02	3.683E 02	8.141E 02	1.732E 00	89.	17.
	VEL	6.030E 00	1.527E-06	3.822E 00	2.423E 01	7.147E 00	2.476E 01	1.448E 00	82.	9.
650.	POS	8.353E 01	1.500E 01	7.311E 01	1.010E 03	4.052E 02	1.042E 03	1.732E 00	87.	14.
	VEL	6.933E 00	3.111E-06	5.294E 00	3.053E 01	7.710E 00	3.120E 01	1.614E 00	81.	8.
660.	POS	9.328E 01	1.500E 01	1.290E 02	1.296E 03	4.427E 02	1.330E 03	1.732E 00	85.	12.
	VEL	7.983E 00	-5.216E-06	7.319E 00	3.872E 01	8.287E 00	3.959E 01	1.799E 00	80.	6.
670.	POS	1.040E 02	1.500E 01	2.087E 02	1.660E 03	4.807E 02	1.698E 03	1.732E 00	83.	10.
	VEL	9.726E 00	-4.147E-05	1.014E 01	4.962E 01	8.877E 00	5.080E 01	2.009E 00	79.	5.
680.	POS	1.158E 02	1.500E 01	3.195E 02	2.132E 03	5.192E 02	2.179E 03	1.732E 00	82.	9.
	VEL	1.073E 01	-2.348E-06	1.415E 01	6.469E 01	9.479E 00	6.634E 01	2.246E 00	78.	4.
690.	POS	1.292E 02	1.500E 01	4.747E 02	2.761E 03	5.581E 02	2.823E 03	1.733E 00	80.	7.
	VEL	1.258E 01	1.580E-05	2.011E 01	8.648E 01	1.009E 01	8.888E 01	2.517E 00	77.	3.

Figure 1.34 SUMMARY DATA FOR RUN NO. 37 (Sheet 2)

RUN NO.= 38 BER BASE

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-62.62000	32.30000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.
6.3709999E 06	-62.77000	32.38000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.
6.3709999E 06	-62.85000	32.33000	5.00000	-0.	-0.	1.5000000E 01	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E-01	1.0000000E-01	1.0000000E-01	1.7379767E 06	-2.4163843E 05	1.4970312E 03
3.0000000E 00	4.9999999E-02	1.0000000E-01	1.0000000E-01	1.0000000E-01	1.7259042E 06	-2.3823537E 05	-9.4754375E 03
3.0000000E 00	4.9999999E-02	1.0000000E-01	1.0000000E-01	1.0000000E-01	1.7179239E 06	-2.3598987E 05	-5.1565937E 03

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
360.	POS	1.206E 02	1.500E 01	1.033E 03	2.666E 03	5.171E 02	2.884E 03	1.729E 00	69.	-8.
	VEL	9.876E 00	-2.174E-05	2.161E 01	6.142E 01	8.859E 00	6.532E 01	2.140E 00	71.	-5.
370.	POS	1.129E 02	1.500E 01	9.119E 02	2.278E 03	4.962E 02	2.481E 03	1.733E 00	68.	-9.
	VEL	8.969E 00	1.160E-05	1.885E 01	5.197E 01	8.533E 00	5.552E 01	1.990E 00	70.	-6.
380.	POS	1.056E 02	1.500E 01	8.079E 02	1.951E 03	4.747E 02	2.141E 03	1.734E 00	68.	-10.
	VEL	8.173E 00	-5.931E-05	1.658E 01	4.433E 01	8.201E 00	4.760E 01	1.854E 00	70.	-7.
390.	POS	9.879E 01	1.500E 01	7.171E 02	1.672E 03	4.526E 02	1.850E 03	1.732E 00	67.	-11.
	VEL	7.466E 00	-4.595E-05	1.467E 01	3.804E 01	7.863E 00	4.107E 01	1.728E 00	69.	-7.
400.	POS	9.217E 01	1.500E 01	6.367E 02	1.430E 03	4.300E 02	1.599E 03	1.732E 00	66.	-12.
	VEL	6.829E 00	-2.029E-05	1.304E 01	3.277E 01	7.519E 00	3.560E 01	1.615E 00	68.	-8.
410.	POS	8.590E 01	1.500E 01	5.648E 02	1.220E 03	4.069E 02	1.379E 03	1.732E 00	65.	-13.
	VEL	6.250E 00	-5.882E-05	1.162E 01	2.829E 01	7.171E 00	3.094E 01	1.511E 00	68.	-9.
420.	POS	7.973E 01	1.500E 01	4.999E 02	1.036E 03	3.832E 02	1.187E 03	1.732E 00	64.	-15.
	VEL	5.719E 00	-1.565E-05	1.037E 01	2.446E 01	6.818E 00	2.693E 01	1.414E 00	67.	-10.
430.	POS	7.373E 01	1.500E 01	4.408E 02	8.732E 02	3.589E 02	1.017E 03	1.733E 00	63.	-16.
	VEL	5.228E 00	-1.444E-05	9.262E 00	2.110E 01	6.462E 00	2.344E 01	1.324E 00	66.	-11.
440.	POS	6.786E 01	1.500E 01	3.867E 02	7.297E 02	3.342E 02	8.662E 02	1.733E 00	62.	-18.
	VEL	4.770E 00	-8.248E-06	8.263E 00	1.817E 01	6.103E 00	2.039E 01	1.238E 00	66.	-13.
450.	POS	6.707E 01	1.500E 01	3.371E 02	6.028E 02	3.089E 02	7.328E 02	1.733E 00	61.	-20.
	VEL	4.340E 00	-1.460E-06	7.362E 00	1.561E 01	5.743E 00	1.770E 01	1.156E 00	65.	-14.
460.	POS	5.639E 01	1.500E 01	2.914E 02	4.909E 02	2.831E 02	6.146E 02	1.734E 00	60.	-23.
	VEL	3.934E 00	-2.417E-06	6.541E 00	1.333E 01	5.383E 00	1.532E 01	1.077E 00	64.	-15.
470.	POS	5.076E 01	1.500E 01	2.494E 02	3.925E 02	2.570E 02	5.103E 02	1.733E 00	58.	-26.
	VEL	3.548E 00	1.014E-05	5.791E 00	1.131E 01	5.023E 00	1.320E 01	9.993E-01	63.	-17.
480.	POS	4.523E 01	1.500E 01	2.107E 02	3.068E 02	2.307E 02	4.189E 02	1.733E 00	56.	-29.
	VEL	3.180E 00	-3.194E-06	5.098E 00	9.504E 00	4.662E 00	1.130E 01	9.230E-01	62.	-19.
490.	POS	3.981E 01	1.500E 01	1.754E 02	2.331E 02	2.043E 02	3.397E 02	1.733E 00	54.	-33.
	VEL	2.826E 00	-1.728E-06	4.453E 00	7.874E 00	4.298E 00	9.585E 00	8.487E-01	61.	-21.
500.	POS	3.456E 01	1.500E 01	1.436E 02	1.709E 02	1.784E 02	2.720E 02	1.733E 00	51.	-37.
	VEL	2.486E 00	2.144E-06	3.839E 00	6.393E 00	3.919E 00	8.019E 00	7.789E-01	59.	-24.
510.	POS	2.960E 01	1.500E 01	1.156E 02	1.201E 02	1.536E 02	2.158E 02	1.734E 00	48.	-42.
	VEL	2.160E 00	3.228E-07	3.234E 00	5.039E 00	3.502E 00	6.560E 00	7.194E-01	58.	-27.
520.	POS	2.516E 01	1.500E 01	9.199E 01	8.043E 01	1.312E 02	1.710E 02	1.734E 00	44.	-48.
	VEL	1.848E 00	-2.041E-06	2.607E 00	3.809E 00	3.000E 00	5.160E 00	6.822E-01	56.	-30.
530.	POS	2.165E 01	1.500E 01	7.389E 01	5.180E 01	1.135E 02	1.387E 02	1.735E 00	39.	-53.
	VEL	1.560E 00	2.756E-07	1.935E 00	2.759E 00	2.371E 00	3.784E 00	6.770E-01	55.	-32.
540.	POS	1.972E 01	1.500E 01	6.264E 01	3.380E 01	1.039E 02	1.205E 02	1.735E 00	31.	-59.
	VEL	1.342E 00	-4.114E-08	1.292E 00	2.072E 00	1.788E 00	2.556E 00	6.343E-01	58.	-32.
550.	POS	1.996E 01	1.500E 01	5.865E 01	2.779E 01	1.057E 02	1.178E 02	1.735E 00	20.	-63.
	VEL	1.968E 00	1.059E-07	9.882E-01	2.022E 00	1.927E 00	2.133E 00	6.118E-01	289.	-47.
560.	POS	2.236E 01	1.500E 01	5.993E 01	3.795E 01	1.186E 02	1.288E 02	1.734E 00	3.	-66.
	VEL	1.654E 00	1.087E-06	1.045E 00	2.691E 00	2.649E 00	3.172E 00	6.461E-01	289.	-44.
570.	POS	2.641E 01	1.500E 01	6.335E 01	6.420E 01	1.398E 02	1.507E 02	1.734E 00	341.	-67.
	VEL	2.025E 00	2.145E-06	1.124E 00	3.851E 00	3.366E 00	4.394E 00	6.829E-01	283.	-36.
580.	POS	3.157E 01	1.500E 01	6.633E 01	1.054E 02	1.663E 02	1.824E 02	1.733E 00	317.	-62.
	VEL	2.438E 00	1.007E-06	1.146E 00	5.359E 00	3.973E 00	5.854E 00	7.465E-01	277.	-28.
590.	POS	3.747E 01	1.500E 01	6.715E 01	1.624E 02	1.962E 02	2.269E 02	1.733E 00	299.	-53.

Figure 1.35 SUMMARY DATA FOR RUN NO. 38 (Sheet 1)

	VEL	2.891E 00	-0.	1.166E 00	7.192E 00	4.514E 00	7.634E 00	8.313E-01	273.	-23.
600.	POS	4.393E 01	1.500E 01	6.467E 01	2.371E 02	2.283E 02	2.899E 02	1.733E 00	287.	-42.
	VEL	3.389E 00	3.498E-06	1.265E 00	9.394E 00	5.030E 00	9.802E 00	9.306E-01	90.	18.
610.	POS	5.087E 01	1.500E 01	5.812E 01	3.322E 02	2.619E 02	3.762E 02	1.733E 00	280.	-32.
	VEL	3.940E 00	6.790E-08	1.526E 00	1.205E 01	5.543E 00	1.245E 01	1.042E 00	87.	15.
620.	POS	5.827E 01	1.500E 01	4.748E 01	4.512E 02	2.966E 02	4.893E 02	1.733E 00	275.	-26.
	VEL	4.555E 00	1.893E-06	2.010E 00	1.528E 01	6.065E 00	1.569E 01	1.164E 00	85.	13.
630.	POS	6.615E 01	1.500E 01	3.613E 01	5.991E 02	3.322E 02	6.333E 02	1.733E 00	272.	-21.
	VEL	5.746E 00	1.183E-06	2.758E 00	1.927E 01	6.600E 00	1.972E 01	1.299E 00	84.	11.
640.	POS	7.455E 01	1.500E 01	4.021E 01	7.825E 02	3.685E 02	8.146E 02	1.733E 00	89.	17.
	VEL	6.032E 00	1.527E-06	3.824E 00	2.423E 01	7.148E 00	2.477E 01	1.448E 00	82.	9.
650.	POS	8.357E 01	1.500E 01	7.314E 01	1.011E 03	4.054E 02	1.042E 03	1.733E 00	87.	14.
	VEL	6.934E 00	3.111E-06	5.296E 00	3.054E 01	7.711E 00	3.121E 01	1.614E 00	81.	8.
660.	POS	9.333E 01	1.500E 01	1.291E 02	1.297E 03	4.429E 02	1.331E 03	1.733E 00	85.	12.
	VEL	7.985E 00	-5.216E-06	7.322E 00	3.873E 01	8.288E 00	3.960E 01	1.800E 00	80.	6.
670.	POS	1.040E 02	1.500E 01	2.088E 02	1.661E 03	4.809E 02	1.699E 03	1.733E 00	83.	10.
	VEL	9.728E 00	-4.147E-05	1.014E 01	4.964E 01	8.878E 00	5.082E 01	2.009E 00	79.	5.
680.	POS	1.158E 02	1.500E 01	3.196E 02	2.133E 03	5.194E 02	2.180E 03	1.733E 00	82.	9.
	VEL	1.073E 01	-2.348E-06	1.416E 01	6.471E 01	9.480E 00	6.636E 01	2.246E 00	78.	4.
690.	POS	1.293E 02	1.500E 01	4.749E 02	2.763E 03	5.584E 02	2.824E 03	1.734E 00	80.	7.
	VEL	1.259E 01	1.580E-05	2.012E 01	8.652E 01	1.009E 01	8.891E 01	2.515E 00	77.	3.

Figure 1.35 SUMMARY DATA FOR RUN NO. 38 (Sheet 2)

RUN NO.= 39 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-57.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-57.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 02	1.0000000E 01	3.0000000E 02	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
3.0000000E 00	4.9999999E-02	3.0000000E 02	1.0000000E 01	3.0000000E 02	2.1238564E 06	-3.9059725E 05	5.6004959E 05
3.0000000E 00	4.9999999E-02	3.0000000E 02	1.0000000E 01	3.0000000E 02	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	3.082E 02	-0.	2.895E 02	4.820E 02	2.646E 02	5.203E 02	2.117E 02	66.	1.
	VEL	2.635E 00	0.	3.889E 00	4.517E 00	2.956E 00	5.898E 00	1.075E 00	50.	9.
670.	POS	3.122E 02	-0.	2.876E 02	4.894E 02	2.831E 02	5.298E 02	2.018E 02	66.	1.
	VEL	2.598E 00	0.	3.409E 00	3.745E 00	2.968E 00	4.985E 00	1.239E 00	49.	15.
680.	POS	3.160E 02	-0.	2.886E 02	4.917E 02	3.035E 02	5.357E 02	1.933E 02	65.	3.
	VEL	2.571E 00	0.	2.961E 00	3.217E 00	2.980E 00	4.302E 00	1.454E 00	51.	25.
690.	POS	3.192E 02	-0.	2.912E 02	4.879E 02	3.255E 02	5.365E 02	1.860E 02	64.	4.
	VEL	2.552E 00	-0.	2.541E 00	3.014E 00	2.993E 00	3.943E 00	1.725E 00	59.	36.
700.	POS	3.214E 02	-0.	2.939E 02	4.774E 02	3.487E 02	5.318E 02	1.795E 02	63.	7.
	VEL	2.543E 00	-0.	2.152E 00	3.190E 00	3.006E 00	3.927E 00	1.943E 00	70.	40.

Figure 1.36 SUMMARY DATA FOR RUN NO. 39

RUN NO.= 40 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-57.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-57.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 03	1.0000000E 01	1.0000000E 03	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
3.0000000E 00	4.9999999E-02	1.0000000E 03	1.0000000E 01	1.0000000E 03	2.1238564E 06	-3.9059725E 05	5.6004959E 05
3.0000000E 00	4.9999999E-02	1.0000000E 03	1.0000000E 01	1.0000000E 03	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	1.027E 03	-0.	9.651E 02	1.606E 03	8.820E 02	1.734E 03	7.053E 02	66.	1.
	VEL	8.778E 00	0.	1.296E 01	1.505E 01	9.852E 00	1.965E 01	3.580E 00	50.	9.
670.	POS	1.040E 03	-0.	9.585E 02	1.631E 03	9.437E 02	1.766E 03	6.724E 02	66.	1.
	VEL	8.656E 00	0.	1.136E 01	1.248E 01	9.891E 00	1.661E 01	4.124E 00	49.	15.
680.	POS	1.05[illegible]E 03	-0.	9.621E 02	1.639E 03	1.012E 03	1.785E 03	6.441E 02	65.	3.
	VEL	8.564E 00	0.	9.866E 00	1.071E 01	9.931E 00	1.433E 01	4.842E 00	51.	25.
690.	POS	1.064E 03	-0.	9.705E 02	1.626E 03	1.085E 03	1.788E 03	6.197E 02	64.	4.
	VEL	8.502E 00	-0.	8.466E 00	1.004E 01	9.972E 00	1.314E 01	5.747E 00	59.	36.
700.	POS	1.071E 03	-0.	9.795E 02	1.591E 03	1.162E 03	1.772E 03	5.981E 02	63.	7.
	VEL	8.472E 00	-0.	7.169E 00	1.063E 01	1.002E 01	1.308E 01	6.476E 00	70.	40.

Figure 1.37 SUMMARY DATA FOR RUN NO. 40

RUN NO.= 41 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-77.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-77.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
1.0000000E 01	1.5000000E-01	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
1.0000000E 01	1.5000000E-01	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.1238564E 06	-3.9059725E 05	5.6004959E 05
1.0000000E 01	1.5000000E-01	3.0000000E 01	1.0000000E 01	3.0000000E 01	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	3.312E 01	-0.	3.063E 01	5.208E 01	2.794E 01	5.571E 01	2.324E 01	67.	1.
	VEL	3.499E-01	0.	4.419E-01	5.585E-01	3.315E-01	6.887E-01	1.909E-01	53.	8.
670.	POS	3.357E 01	-0.	3.035E 01	5.311E 01	2.986E 01	5.694E 01	2.215E 01	67.	1.
	VEL	3.415E-01	0.	3.939E-01	4.924E-01	3.377E-01	6.026E-01	2.020E-01	54.	11.
680.	POS	3.403E 01	-0.	3.043E 01	5.361E 01	3.200E 01	5.779E 01	2.123E 01	66.	2.
	VEL	3.360E-01	0.	3.507E-01	4.494E-01	3.447E-01	5.391E-01	2.152E-01	56.	17.
690.	POS	3.445E 01	-0.	3.070E 01	5.347E 01	3.431E 01	5.812E 01	2.046E 01	66.	4.
	VEL	3.324E-01	-0.	3.118E-01	4.322E-01	3.523E-01	5.043E-01	2.283E-01	62.	24.
700.	POS	3.477E 01	-0.	3.102E 01	5.263E 01	3.677E 01	5.784E 01	1.982E 01	65.	7.
	VEL	3.314E-01	-0.	2.774E-01	4.427E-01	3.605E-01	5.017E-01	2.331E-01	69.	28.

Figure 1.38 SUMMARY DATA FOR RUN NO. 41

RUN NO.= 42 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709^99E 06	-^7.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-^7.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
1.000^000E 01	1.5000000E-01	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
1.000^000E 01	1.5000000E-01	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.1238564E 06	-3.9059725E 05	5.6004959E 05
1.000^000E 01	1.5000000E-01	1.0000000E 02	1.0000000E 01	1.0000000E 02	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	1.^34E 02	-0.	9.703E 01	1.618E 02	8.865E 01	1.745E 02	7.119E 01	66.	1.
	VEL	9.141E-01	0.	1.313E 00	1.540E 00	9.965E-01	1.997E 00	3.929E-01	50.	9.
670.	POS	1.^48E 02	-0.	9.634E 01	1.644E 02	9.485E 01	1.778E 02	6.787E 01	66.	1.
	VEL	8.^82E-01	0.	1.153E 00	1.288E 00	1.002E 00	1.694E 00	4.450E-01	50.	15.
680.	POS	1.^61E 02	-0.	9.669E 01	1.652E 02	1.017E 02	1.798E 02	6.502E 01	65.	3.
	VEL	8.^63E-01	0.	1.004E 00	1.116E 00	1.008E 00	1.468E 00	5.136E-01	52.	24.
690.	POS	1.^72E 02	-0.	9.754E 01	1.641E 02	1.090E 02	1.802E 02	6.257E 01	64.	4.
	VEL	8.^786E-01	-0.	8.657E-01	1.051E 00	1.014E 00	1.348E 00	5.986E-01	59.	35.
700.	POS	1.^79E 02	-0.	9.845E 01	1.606E 02	1.168E 02	1.787E 02	6.041E 01	63.	7.
	VEL	8.^51E-01	-0.	7.379E-01	1.106E 00	1.021E 00	1.343E 00	6.605E-01	70.	38.

Figure 1.39 SUMMARY DATA FOR RUN NO. 42

RUN NO.= 43 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-57.60000	36.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-57.60000	27.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-43.70000	31.60000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.2273567E 06	-4.1702994E 05	-4.2280256E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	2.1238564E 06	-3.9059725E 05	5.6004959E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	3.0000000E 00	3.0000000E 01	3.3544083E 06	-9.5809599E 05	1.9507397E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
660.	POS	3.103E 01	-0.	2.911E 01	4.855E 01	2.660E 01	5.236E 01	2.136E 01	66.	1.
	VEL	2.763E-01	0.	3.944E-01	4.637E-01	2.996E-01	6.002E-01	1.201E-01	50.	9.
670.	POS	3.143E 01	-0.	2.890E 01	4.932E 01	2.845E 01	5.334E 01	2.036E 01	66.	1.
	VEL	2.713E-01	0.	3.465E-01	3.885E-01	3.013E-01	5.098E-01	1.355E-01	50.	14.
680.	POS	3.182E 01	-0.	2.901E 01	4.957E 01	3.050E 01	5.395E 01	1.951E 01	65.	3.
	VEL	2.676E-01	0.	3.020E-01	3.375E-01	3.032E-01	4.421E-01	1.559E-01	52.	24.
690.	POS	3.216E 01	-0.	2.926E 01	4.922E 01	3.271E 01	5.405E 01	1.877E 01	64.	4.
	VEL	2.652E-01	-0.	2.606E-01	3.179E-01	3.052E-01	4.063E-01	1.810E-01	59.	34.
700.	POS	3.238E 01	-0.	2.954E 01	4.819E 01	3.505E 01	5.360E 01	1.812E 01	63.	7.
	VEL	2.641E-01	-0.	2.224E-01	3.345E-01	3.074E-01	4.049E-01	1.987E-01	70.	38.

Figure 1.40 SUMMARY DATA FOR RUN NO. 43

RUN NO.= 44 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-56.20000	34.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-56.20000	29.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-52.00000	31.90000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.3216519E 06	-4.3912712E 05	-1.1160028E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.2774060E 06	-4.3144237E 05	3.5314925E 05
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	2.6648259E 06	-5.8604181E 05	1.5033344E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
540.	POS	7.737E 01	0.	2.312E 02	3.596E 02	5.834E 01	4.275E 02	1.578E 01	57.	2.
	VEL	9.302E-01	-0.	4.267E 00	8.782E 00	6.576E-01	9.766E 00	1.362E-01	64.	2.
550.	POS	6.475E 01	0.	1.926E 02	2.811E 02	5.248E 01	3.406E 02	1.572E 01	56.	2.
	VEL	8.652E-01	-0.	3.605E 00	7.167E 00	6.457E-01	8.024E 00	1.332E-01	63.	2.
560.	POS	5.770E 01	0.	1.600E 02	2.170E 02	4.682E 01	2.693E 02	1.567E 01	54.	3.
	VEL	8.111E-01	-0.	3.081E 00	5.888E 00	6.381E-01	6.647E 00	1.321E-01	62.	2.
570.	POS	5.106E 01	0.	1.321E 02	1.645E 02	4.138E 01	2.106E 02	1.565E 01	51.	3.
	VEL	7.662E-01	-0.	2.656E 00	4.851E 00	6.332E-01	5.531E 00	1.335E-01	61.	2.
580.	POS	4.489E 01	0.	1.083E 02	1.217E 02	3.624E 01	1.623E 02	1.567E 01	48.	3.
	VEL	7.292E-01	-0.	2.303E 00	3.991E 00	6.302E-01	4.608E 00	1.378E-01	60.	2.
590.	POS	3.923E 01	0.	8.788E 01	8.718E 01	3.153E 01	1.229E 02	1.579E 01	45.	3.
	VEL	6.993E-01	-0.	2.004E 00	3.263E 00	6.284E-01	3.829E 00	1.459E-01	59.	2.
600.	POS	3.420E 01	0.	7.053E 01	6.008E 01	2.745E 01	9.130E 01	1.608E 01	40.	2.
	VEL	6.755E-01	-0.	1.744E 00	2.634E 00	6.276E-01	3.158E 00	1.591E-01	57.	3.
610.	POS	3.001E 01	0.	5.604E 01	4.012E 01	2.431E 01	6.690E 01	1.664E 01	34.	1.
	VEL	6.573E-01	-0.	1.514E 00	2.082E 00	6.275E-01	2.571E 00	1.795E-01	54.	3.
620.	POS	2.695E 01	0.	4.435E 01	2.769E 01	2.254E 01	4.922E 01	1.764E 01	28.	-1.
	VEL	6.440E-01	-0.	1.305E 00	1.592E 00	6.281E-01	2.051E 00	2.110E-01	51.	4.
630.	POS	2.525E 01	-0.	3.554E 01	2.275E 01	2.245E 01	3.770E 01	1.921E 01	22.	-6.
	VEL	6.351E-01	0.	1.113E 00	1.160E 00	6.293E-01	1.590E 00	2.603E-01	46.	6.
640.	POS	2.472E 01	-0.	2.971E 01	2.232E 01	2.409E 01	3.144E 01	2.029E 01	21.	-15.
	VEL	6.304E-01	0.	9.303E-01	8.087E-01	6.314E-01	1.191E 00	3.386E-01	41.	11.
650.	POS	2.472E 01	-0.	2.664E 01	2.237E 01	2.716E 01	2.916E 01	1.919E 01	12.	-41.
	VEL	6.796E-01	0.	7.551E-01	6.331E-01	6.343E-01	8.810E-01	4.519E-01	39.	25.
660.	POS	2.461E 01	-0.	2.558E 01	2.112E 01	3.125E 01	3.264E 01	1.697E 01	292.	-70.
	VEL	6.325E-01	0.	5.852E-01	7.573E-01	6.377E-01	8.247E-01	4.754E-01	271.	-32.
670.	POS	2.429E 01	-0.	2.542E 01	1.962E 01	3.604E 01	3.816E 01	1.462E 01	277.	-69.
	VEL	6.391E-01	0.	4.253E-01	1.098E 00	6.416E-01	1.120E 00	3.631E-01	276.	-11.
680.	POS	2.543E 01	-0.	2.521E 01	2.250E 01	4.128E 01	4.455E 01	1.445E 01	275.	-66.
	VEL	6.496E-01	0.	3.035E-01	1.546E 00	6.459E-01	1.552E 00	2.746E-01	90.	6.
690.	POS	3.009E 01	-0.	2.429E 01	3.423E 01	4.686E 01	5.246E 01	1.724E 01	275.	-59.
	VEL	6.641E-01	0.	3.059E-01	2.070E 00	6.506E-01	2.082E 00	2.177E-01	85.	4.
700.	POS	3.667E 01	-0.	2.248E 01	5.456E 01	5.266E 01	6.476E 01	1.832E 01	275.	-42.
	VEL	6.834E-01	-0.	4.669E-01	2.677E 00	6.559E-01	2.713E 00	1.812E-01	81.	3.

Figure 1.41 SUMMARY DATA FOR RUN NO. 44

RUN NO.= 45 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-56.20000	34.00000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-56.20000	29.80000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-52.00000	31.90000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.3216519E 06	-4.3912712E 05	-1.1160028E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.2774060E 06	-4.3144237E 05	3.5314925E 05
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	2.6648259E 06	-5.8604181E 05	1.5033344E 05

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
540.	POS	2.354E 02	0.	7.529E 02	1.171E 03	1.896E 02	1.392E 03	5.134E 01	57.	2.
	VEL	2.650E 00	-0.	1.394E 01	2.870E 01	2.145E 00	3.192E 01	2.955E-01	64.	2.
550.	POS	2.103E 02	0.	6.262E 02	9.136E 02	1.701E 02	1.107E 03	5.103E 01	56.	2.
	VEL	2.515E 00	-0.	1.177E 01	2.341E 01	2.110E 00	2.621E 01	3.064E-01	63.	2.
560.	POS	1.868E 02	0.	5.191E 02	7.037E 02	1.513E 02	8.737E 02	5.075E 01	54.	3.
	VEL	2.403E 00	-0.	1.006E 01	1.921E 01	2.089E 00	2.169E 01	3.215E-01	62.	2.
570.	POS	1.649E 02	0.	4.278E 02	5.321E 02	1.333E 02	6.815E 02	5.052E 01	51.	3.
	VEL	2.310E 00	-0.	8.668E 00	1.581E 01	2.076E 00	1.804E 01	3.421E-01	61.	2.
580.	POS	1.444E 02	0.	3.497E 02	3.923E 02	1.162E 02	5.236E 02	5.043E 01	48.	3.
	VEL	2.233E 00	-0.	7.513E 00	1.299E 01	2.070E 00	1.501E 01	3.699E-01	60.	2.
590.	POS	1.257E 02	0.	2.828E 02	2.797E 02	1.006E 02	3.949E 02	5.060E 01	45.	3.
	VEL	2.170E 00	-0.	6.533E 00	1.060E 01	2.067E 00	1.246E 01	4.077E-01	58.	2.
600.	POS	1.090E 02	0.	2.261E 02	1.917E 02	8.718E 01	2.922E 02	5.125E 01	40.	2.
	VEL	2.120E 00	-0.	5.683E 00	8.536E 00	2.067E 00	1.025E 01	4.596E-01	56.	3.
610.	POS	9.530E 01	0.	1.789E 02	1.273E 02	7.706E 01	2.132E 02	5.273E 01	34.	1.
	VEL	2.080E 00	-0.	4.929E 00	6.718E 00	2.069E 00	8.325E 00	5.331E-01	54.	3.
620.	POS	8.549E 01	0.	1.411E 02	8.774E 01	7.166E 01	1.565E 02	5.561E 01	28.	-2.
	VEL	2.051E 00	-0.	4.245E 00	5.100E 00	2.072E 00	6.616E 00	6.406E-01	50.	5.
630.	POS	8.036E 01	-0.	1.130E 02	7.261E 01	7.210E 01	1.205E 02	6.058E 01	23.	-8.
	VEL	2.031E 00	0.	3.611E 00	3.670E 00	2.077E 00	5.099E 00	8.050E-01	46.	7.
640.	POS	7.899E 01	-0.	9.496E 01	7.128E 01	7.831E 01	1.019E 02	6.325E 01	23.	-17.
	VEL	2.021E 00	0.	3.010E 00	2.505E 00	2.082E 00	3.787E 00	1.064E 00	39.	12.
650.	POS	7.883E 01	-0.	8.612E 01	7.037E 01	8.914E 01	9.583E 01	5.801E 01	15.	-41.
	VEL	2.020E 00	0.	2.429E 00	1.955E 00	2.089E 00	2.789E 00	1.432E 00	37.	29.
660.	POS	7.739E 01	-0.	8.370E 01	6.432E 01	1.032E 02	1.075E 02	4.859E 01	293.	-72.
	VEL	2.028E 00	0.	1.863E 00	2.448E 00	2.097E 00	2.688E 00	1.463E 00	276.	-32.
670.	POS	7.403E 01	-0.	8.389E 01	5.714E 01	1.193E 02	1.260E 02	3.785E 01	277.	-70.
	VEL	2.045E 00	0.	1.327E 00	3.631E 00	2.105E 00	3.707E 00	1.096E 00	277.	-11.
680.	POS	7.759E 01	-0.	8.352E 01	6.691E 01	1.369E 02	1.472E 02	3.765E 01	274.	-67.
	VEL	2.073E 00	0.	9.214E-01	5.135E 00	2.114E 00	5.156E 00	8.207E-01	90.	6.
690.	POS	9.676E 01	-0.	8.060E 01	1.086E 02	1.555E 02	1.733E 02	5.342E 01	275.	-60.
	VEL	2.111E 00	0.	9.612E-01	6.877E 00	2.124E 00	6.919E 00	6.445E-01	85.	4.
700.	POS	1.205E 02	-0.	7.457E 01	1.783E 02	1.747E 02	2.137E 02	6.000E 01	275.	-43.
	VEL	2.161E 00	-0.	1.532E 00	8.881E 00	2.136E 00	9.001E 00	5.298E-01	81.	3.

Figure 1.42 SUMMARY DATA FOR RUN NO. 45

RUN NO.= 46 ALL SHIPS

R	LCNG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-64.60000	31.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-64.60000	32.40000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-63.70000	31.90000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	1.5494639E 06	-1.9140094E 05	3.6803781E 04
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	1.5624774E 06	-1.9469744E 05	-3.9865750E 04
3.0000000E 00	4.9999999E-02	3.0000000E 01	1.0000000E 01	3.0000000E 01	1.6342780E 06	-2.1324712E 05	2.9202313E 04

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
330.	POS	3.105E 02	0.	1.443E 03	3.895E 03	4.551E 02	4.156E 03	1.647E 01	70.	-2.
	VEL	4.321E 00	-0.	1.877E 01	6.536E 01	2.146E 00	6.800E 01	5.718E-01	74.	-0.
340.	POS	2.896E 02	0.	1.272E 03	3.304E 03	4.352E 02	3.542E 03	1.640E 01	69.	-2.
	VEL	3.991E 00	-0.	1.593E 01	5.420E 01	2.181E 00	5.650E 01	5.343E-01	74.	-1.
350.	POS	2.700E 02	0.	1.125E 03	2.810E 03	4.148E 02	3.029E 03	1.632E 01	68.	-2.
	VEL	3.705E 00	-0.	1.378E 01	4.568E 01	2.217E 00	4.771E 01	4.990E-01	73.	-1.
360.	POS	2.515E 02	0.	9.978E 02	2.390E 03	3.938E 02	2.593E 03	1.624E 01	67.	-3.
	VEL	3.455E 00	-0.	1.210E 01	3.899E 01	2.255E 00	4.083E 01	4.652E-01	73.	-1.
370.	POS	2.339E 02	0.	8.852E 02	2.031E 03	3.724E 02	2.218E 03	1.615E 01	66.	-3.
	VEL	3.233E 00	-0.	1.076E 01	3.364E 01	2.295E 00	3.532E 01	4.338E-01	72.	-1.
380.	POS	2.169E 02	0.	7.844E 02	1.719E 03	3.505E 02	1.892E 03	1.604E 01	65.	-3.
	VEL	3.036E 00	-0.	9.679E 00	2.925E 01	2.338E 00	3.081E 01	4.044E-01	72.	-1.
390.	POS	2.004E 02	0.	6.934E 02	1.447E 03	3.280E 02	1.607E 03	1.592E 01	64.	-3.
	VEL	2.858E 00	-0.	8.781E 00	2.559E 01	2.382E 00	2.706E 01	3.778E-01	71.	-1.
400.	POS	1.843E 02	0.	6.106E 02	1.209E 03	3.051E 02	1.357E 03	1.578E 01	63.	-4.
	VEL	2.699E 00	-0.	8.026E 00	2.247E 01	2.429E 00	2.387E 01	3.537E-01	70.	-2.
410.	POS	1.685E 02	0.	5.346E 02	9.993E 02	2.816E 02	1.136E 03	1.562E 01	62.	-4.
	VEL	2.555E 00	-0.	7.380E 00	1.978E 01	2.479E 00	2.112E 01	3.329E-01	70.	-2.
420.	POS	1.530E 02	0.	4.646E 02	8.147E 02	2.576E 02	9.407E 02	1.542E 01	60.	-5.
	VEL	2.427E 00	-0.	6.819E 00	1.741E 01	2.531E 00	1.871E 01	3.159E-01	69.	-2.
430.	POS	1.376E 02	0.	3.999E 02	6.525E 02	2.331E 02	7.681E 02	1.518E 01	59.	-5.
	VEL	2.315E 00	-0.	6.323E 00	1.528E 01	2.587E 00	1.655E 01	3.037E-01	68.	-3.
440.	POS	1.223E 02	0.	3.398E 02	5.105E 02	2.081E 02	6.160E 02	1.488E 01	56.	-6.
	VEL	2.220E 00	-0.	5.876E 00	1.333E 01	2.645E 00	1.459E 01	2.977E-01	66.	-3.
450.	POS	1.070E 02	0.	2.840E 02	3.872E 02	1.827E 02	4.828E 02	1.450E 01	54.	-7.
	VEL	2.145E 00	-0.	5.465E 00	1.152E 01	2.706E 00	1.278E 01	3.002E-01	65.	-4.
460.	POS	9.183E 01	0.	2.323E 02	2.815E 02	1.569E 02	3.673E 02	1.399E 01	51.	-8.
	VEL	2.090E 00	-0.	5.081E 00	9.802E 00	2.770E 00	1.107E 01	3.142E-01	63.	-5.
470.	POS	7.672E 01	0.	1.845E 02	1.927E 02	1.310E 02	2.688E 02	1.330E 01	47.	-9.
	VEL	2.059E 00	-0.	4.713E 00	8.140E 00	2.838E 00	9.446E 00	3.451E-01	60.	-6.
480.	POS	6.181E 01	0.	1.408E 02	1.207E 02	1.056E 02	1.868E 02	1.234E 01	41.	-11.
	VEL	2.051E 00	-0.	4.353E 00	6.504E 00	2.909E 00	7.881E 00	4.011E-01	56.	-8.
490.	POS	4.743E 01	0.	1.017E 02	6.552E 01	8.155E 01	1.214E 02	1.096E 01	33.	-13.
	VEL	2.063E 00	-0.	3.993E 00	4.871E 00	2.984E 00	6.378E 00	4.978E-01	51.	-11.
500.	POS	3.468E 01	0.	6.850E 01	2.858E 01	6.192E 01	7.386E 01	9.160E 00	23.	-19.
	VEL	2.093E 00	-0.	3.624E 00	3.235E 00	3.062E 00	4.988E 00	6.644E-01	42.	-19.
510.	POS	2.716E 01	-0.	4.538E 01	1.464E 01	5.331E 01	5.521E 01	8.115E 00	42.	-70.
	VEL	2.137E 00	0.	3.238E 00	1.715E 00	3.146E 00	3.927E 00	9.377E-01	27.	-37.
520.	POS	2.784E 01	-0.	4.096E 01	1.621E 01	6.193E 01	6.525E 01	8.709E 00	30.	-69.
	VEL	2.191E 00	0.	2.829E 00	1.444E 00	3.236E 00	3.538E 00	1.147E 00	360.	-56.
530.	POS	3.643E 01	-0.	5.296E 01	2.709E 01	8.363E 01	8.861E 01	1.077E 01	11.	-68.
	VEL	2.356E 00	0.	2.387E 00	3.085E 00	3.335E 00	3.917E 00	9.197E-01	310.	-29.
540.	POS	5.143E 01	-0.	6.872E 01	6.281E 01	1.118E 02	1.187E 02	1.381E 01	344.	-65.
	VEL	2.328E 00	0.	1.897E 00	5.261E 00	3.433E 00	5.592E 00	6.697E-01	289.	-10.
550.	POS	6.871E 01	-0.	8.194E 01	1.241E 02	1.430E 02	1.595E 02	1.565E 01	311.	-45.
	VEL	2.372E 00	0.	1.329E 00	7.581E 00	3.457E 00	7.711E 00	5.113E-01	279.	-6.
560.	POS	8.691E 01	-0.	9.028E 01	2.107E 02	1.756E 02	2.327E 02	1.658E 01	294.	-19.

Figure 1.43 SUMMARY DATA FOR RUN NO. 46 (Sheet 1)

	VEL	2.444E 00	0.	7.560E-01	1.012E 01	3.480E 00	1.016E 01	4.224E-01	273.	-5.
570.	POS	1.058E 02	-0.	9.263E 01	3.245E 02	2.090E 02	3.398E 02	1.704E 01	285.	-11.
	VEL	2.549E 00	0.	4.575E-01	1.294E 01	3.504E 00	1.297E 01	3.737E-01	89.	4.
580.	POS	1.253E 02	-0.	8.809E 01	4.685E 02	2.429E 02	4.790E 02	1.727E 01	280.	-8.
	VEL	2.692E 00	0.	1.017E 00	1.615E 01	3.528E 00	1.620E 01	3.504E-01	87.	3.
590.	POS	1.455E 02	-0.	7.588E 01	6.472E 02	2.772E 02	6.540E 02	1.738E 01	276.	-6.
	VEL	2.977E 00	0.	1.910E 00	1.988E 01	3.553E 00	1.999E 01	3.449E-01	85.	2.
600.	POS	1.666E 02	-0.	5.624E 01	8.665E 02	3.119E 02	8.707E 02	1.742E 01	273.	-5.
	VEL	3.108E 00	0.	3.014E 00	2.431E 01	3.578E 00	2.451E 01	3.525E-01	83.	2.
610.	POS	1.886E 02	-0.	3.773E 01	1.134E 03	3.469E 02	1.138E 03	1.743E 01	270.	-4.
	VEL	3.388E 00	-0.	4.370E 00	2.969E 01	3.605E 00	3.002E 01	3.704E-01	82.	2.
620.	POS	2.118E 02	0.	5.913E 01	1.462E 03	3.821E 02	1.466E 03	1.742E 01	88.	4.
	VEL	3.722E 00	-0.	6.067E 00	3.637E 01	3.633E 00	3.688E 01	3.968E-01	81.	1.
630.	POS	2.365E 02	0.	1.225E 02	1.865E 03	4.176E 02	1.872E 03	1.739E 01	86.	3.
	VEL	4.116E 00	-0.	8.237E 00	4.488E 01	3.662E 00	4.564E 01	4.306E-01	80.	1.
640.	POS	2.629E 02	0.	2.157E 02	2.365E 03	4.533E 02	2.378E 03	1.735E 01	85.	3.
	VEL	4.583E 00	-0.	1.109E 01	5.605E 01	3.692E 00	5.714E 01	4.712E-01	79.	1.
650.	POS	2.917E 02	0.	3.435E 02	2.995E 03	4.892E 02	3.017E 03	1.732E 01	84.	2.
	VEL	5.140E 00	-0.	1.497E 01	7.117E 01	3.724E 00	7.273E 01	5.183E-01	78.	1.
660.	POS	3.734E 02	0.	5.178E 02	3.805E 03	5.254E 02	3.842E 03	1.727E 01	82.	2.
	VEL	5.815E 00	-0.	2.043E 01	9.247E 01	3.758E 00	9.470E 01	5.717E-01	78.	1.

Figure 1.43 SUMMARY DATA FOR RUN NO. 46 (Sheet 2)

RUN NO.= 47 ALL SHIPS

R	LONG.	LAT.	MIN EL.	DEL R	DEL RDOT	DEL X	DEL Y	DEL Z
6.3709999E 06	-64.60000	31.70000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-64.60000	32.40000	5.00000	-0.	-0.	-0.	-0.	-0.
6.3709999E 06	-63.70000	31.90000	5.00000	-0.	-0.	-0.	-0.	-0.

SIGMA R	SIGMA RDOT	SIGMA X	SIGMA Y	SIGMA Z	XS	YS	ZS
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	1.5494639E 06	-1.9140094E 05	3.6803781E 04
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	1.5624774E 06	-1.9469744E 05	-3.9865750E 04
3.0000000E 00	4.9999999E-02	1.0000000E 02	1.0000000E 01	1.0000000E 02	1.6342780E 06	-2.1324712E 05	2.9202313E 04

TIME	P,V	RHO	DEL X	X ERROR	Y ERROR	Z ERROR	MAX AXIS	MIN AXIS	AZ MAX	EL MAX
330.	POS	1.023E 03	0.	4.752E 03	1.283E 04	1.499E 03	1.369E 04	5.423E 01	70.	-2.
	VEL	9.510E 00	-0.	6.153E 01	2.149E 02	6.660E 00	2.235E 02	6.007E-01	74.	-0.
340.	POS	9.531E 02	0.	4.187E 03	1.088E 04	1.432E 03	1.166E 04	5.397E 01	69.	-2.
	VEL	8.825E 00	-0.	5.220E 01	1.781E 02	6.819E 00	1.856E 02	5.653E-01	74.	-1.
350.	POS	8.882E 02	0.	3.702E 03	9.243E 03	1.364E 03	9.964E 03	5.370E 01	68.	-2.
	VEL	8.239E 00	-0.	4.512E 01	1.500E 02	6.982E 00	1.567E 02	5.311E-01	73.	-1.
360.	POS	8.268E 02	0.	3.280E 03	7.858E 03	1.294E 03	8.523E 03	5.338E 01	67.	-2.
	VEL	7.728E 00	-0.	3.961E 01	1.280E 02	7.148E 00	1.340E 02	5.004E-01	73.	-1.
370.	POS	7.681E 02	0.	2.907E 03	6.670E 03	1.223E 03	7.284E 03	5.303E 01	66.	-3.
	VEL	7.278E 00	-0.	3.523E 01	1.104E 02	7.318E 00	1.159E 02	4.733E-01	72.	-1.
380.	POS	7.116E 02	0.	2.574E 03	5.641E 03	1.150E 03	6.209E 03	5.263E 01	65.	-3.
	VEL	6.883E 00	-0.	3.167E 01	9.600E 01	7.494E 00	1.011E 02	4.496E-01	72.	-1.
390.	POS	6.567E 02	0.	2.273E 03	4.743E 03	1.075E 03	5.269E 03	5.218E 01	64.	-3.
	VEL	6.539E 00	-0.	2.874E 01	8.397E 01	7.675E 00	8.878E 01	4.286E-01	71.	-1.
400.	POS	6.032E 02	0.	1.999E 03	3.957E 03	9.980E 02	4.442E 03	5.165E 01	63.	-4.
	VEL	6.240E 00	-0.	2.628E 01	7.375E 01	7.861E 00	7.832E 01	4.124E-01	70.	-2.
410.	POS	5.506E 02	0.	1.747E 03	3.265E 03	9.195E 02	3.713E 03	5.103E 01	62.	-4.
	VEL	5.983E 00	-0.	2.417E 01	6.490E 01	8.054E 00	6.929E 01	4.014E-01	70.	-2.
420.	POS	4.987E 02	0.	1.516E 03	2.657E 03	8.393E 02	3.068E 03	5.028E 01	60.	-5.
	VEL	5.768E 00	-0.	2.235E 01	5.710E 01	8.253E 00	6.136E 01	3.968E-01	69.	-2.
430.	POS	4.473E 02	0.	1.301E 03	2.122E 03	7.572E 02	2.498E 03	4.937E 01	59.	-5.
	VEL	5.596E 00	-0.	2.073E 01	5.009E 01	8.460E 00	5.427E 01	4.002E-01	68.	-3.
440.	POS	3.961E 02	0.	1.102E 03	1.654E 03	6.734E 02	1.996E 03	4.822E 01	56.	-6.
	VEL	5.467E 00	-0.	1.928E 01	4.368E 01	8.674E 00	4.782E 01	4.137E-01	66.	-3.
450.	POS	3.450E 02	0.	9.165E 02	1.249E 03	5.879E 02	1.557E 03	4.674E 01	54.	-7.
	VEL	5.381E 00	-0.	1.794E 01	3.770E 01	8.896E 00	4.184E 01	4.407E-01	65.	-4.
460.	POS	2.939E 02	0.	7.446E 02	9.009E 02	5.010E 02	1.176E 03	4.478E 01	51.	-8.
	VEL	5.338E 00	-0.	1.669E 01	3.202E 01	9.127E 00	3.622E 01	4.859E-01	62.	-5.
470.	POS	2.427E 02	0.	5.853E 02	6.093E 02	4.132E 02	8.503E 02	4.206E 01	46.	-9.
	VEL	5.335E 00	-0.	1.548E 01	2.650E 01	9.367E 00	3.085E 01	5.574E-01	60.	-6.
480.	POS	1.915E 02	0.	4.388E 02	3.727E 02	3.258E 02	5.785E 02	3.813E 01	41.	-10.
	VEL	5.369E 00	-0.	1.431E 01	2.106E 01	9.618E 00	2.567E 01	6.697E-01	56.	-8.
490.	POS	1.408E 02	0.	3.058E 02	1.914E 02	2.417E 02	3.598E 02	3.219E 01	32.	-10.
	VEL	5.437E 00	-0.	1.312E 01	1.558E 01	9.879E 00	2.070E 01	8.502E-01	50.	-12.
500.	POS	9.183E 01	0.	1.897E 02	6.821E 01	1.709E 02	1.981E 02	2.253E 01	17.	2.
	VEL	5.534E 00	-0.	1.191E 01	1.000E 01	1.015E 01	1.614E 01	1.151E 00	41.	-20.
510.	POS	6.162E 01	-0.	1.047E 02	2.867E 01	1.416E 02	1.441E 02	1.559E 01	304.	78.
	VEL	5.658E 00	0.	1.064E 01	4.505E 00	1.044E 01	1.281E 01	1.625E 00	25.	-39.
520.	POS	6.813E 01	-0.	1.002E 02	3.951E 01	1.810E 02	1.887E 02	1.829E 01	36.	-72.
	VEL	5.806E 00	0.	9.282E 00	3.716E 00	1.074E 01	1.171E 01	1.938E 00	357.	-56.
530.	POS	1.055E 02	-0.	1.584E 02	7.242E 01	2.631E 02	2.784E 02	2.896E 01	12.	-69.
	VEL	5.978E 00	0.	7.803E 00	9.928E 00	1.106E 01	1.300E 01	1.565E 00	311.	-30.
540.	POS	1.635E 02	-0.	2.196E 02	1.955E 02	3.627E 02	3.848E 02	4.351E 01	345.	-66.
	VEL	6.165E 00	0.	6.149E 00	1.735E 01	1.136E 01	1.853E 01	1.137E 00	289.	-10.
550.	POS	2.242E 02	-0.	2.677E 02	4.025E 02	4.697E 02	5.222E 02	5.100E 01	312.	-46.
	VEL	6.259E 00	0.	4.213E 00	2.513E 01	1.142E 01	2.557E 01	8.583E-01	279.	-6.
560.	POS	2.863E 02	-0.	2.975E 02	6.925E 02	5.798E 02	7.659E 02	5.460E 01	294.	-20.

Figure 1.44 SUMMARY DATA FOR RUN NO. 47 (Sheet 1)

	VEL	6.399E 00	0.	2.187E 00	3.356E 01	1.147E 01	3.372E 01	6.936E-01	273.	-5.
570.	POS	3.499E 02	-0.	3.065E 02	1.072E 03	6.919E 02	1.123E 03	5.636E 01	286.	-11.
	VEL	6.593E 00	0.	1.030E 00	4.293E 01	1.153E 01	4.301E 01	5.930E-01	89.	4.
580.	POS	4.152E 02	-0.	2.919E 02	1.552E 03	8.052E 02	1.587E 03	5.723E 01	280.	-8.
	VEL	6.852E 00	0.	3.235E 00	5.355E 01	1.158E 01	5.371E 01	5.313E-01	87.	3.
590.	POS	4.826E 02	-0.	2.517E 02	2.146E 03	9.197E 02	2.169E 03	5.764E 01	276.	-6.
	VEL	7.188E 00	0.	6.295E 00	6.587E 01	1.164E 01	6.623E 01	4.957E-01	85.	2.
600.	POS	5.527E 02	-0.	1.866E 02	2.875E 03	1.035E 03	2.889E 03	5.781E 01	273.	-5.
	VEL	7.614E 00	0.	9.990E 00	8.049E 01	1.169E 01	8.116E 01	4.792E-01	83.	2.
610.	POS	6.758E 02	-0.	1.252E 02	3.764E 03	1.151E 03	3.775E 03	5.784E 01	270.	-4.
	VEL	8.145E 00	-0.	1.450E 01	9.823E 01	1.175E 01	9.933E 01	4.774E-01	82.	2.
620.	POS	7.028E 02	0.	1.962E 02	4.852E 03	1.268E 03	4.864E 03	5.779E 01	88.	4.
	VEL	8.796E 00	-0.	2.012E 01	1.203E 02	1.180E 01	1.220E 02	4.878E-01	81.	1.
630.	POS	7.845E 02	0.	4.065E 02	6.188E 03	1.385E 03	6.209E 03	5.769E 01	86.	3.
	VEL	9.589E 00	-0.	2.731E 01	1.483E 02	1.186E 01	1.509E 02	5.089E-01	80.	1.
640.	POS	8.721E 02	0.	7.154E 02	7.846E 03	1.503E 03	7.886E 03	5.756E 01	85.	3.
	VEL	1.055E 01	-0.	3.675E 01	1.852E 02	1.192E 01	1.888E 02	5.391E-01	79.	1.
650.	POS	9.672E 02	0.	1.139E 03	9.933E 03	1.622E 03	1.000E 04	5.742E 01	84.	2.
	VEL	1.171E 01	-0.	4.956E 01	2.351E 02	1.198E 01	2.403E 02	5.757E-01	78.	1.
660.	POS	1.072E 03	0.	1.717E 03	1.261E 04	1.741E 03	1.274E 04	5.726E 01	82.	2.
	VEL	1.314E 01	-0.	6.762E 01	3.054E 02	1.204E 01	3.128E 02	6.222E-01	78.	1.

Figure 1.44 SUMMARY DATA FOR RUN NO. 47 (Sheet 2)

1.3 AROD/COMPUTER INTERFACE

During the first quarter, meetings and discussions were held with NASA and IBM personnel to identify problem areas in the implementation of the interface between the AROD equipment and the Saturn computer, and to generate a preliminary design approach for this interface. This design approach, and the unresolved problem areas, are the subjects of this section.

1.3.1 Functional Flow

A general functional flow for the AROD information is presented below. The equipment configurations that have been assumed for the Saturn computer and the Data Adapter, which provides the input/output buffering for the computer, are described in two IBM Owego documents:

a. The Saturn V Digital Computer, report number TN 587-38

b. The Saturn V Data Adapter, report number TN 587-36

Assuming the use of this equipment, the following information flow for the AROD data could be employed:

1. The AROD equipment measures, and stores, range and range rate to each of four ground transponders.
2. The Saturn computer, when it reaches the AROD portion of its computation cycle, summons the AROD data by sending a PIO instruction (for each AROD word) to the Data Adapter with the AROD address.
3. The Data Adapter decodes the PIO-AROD instruction, generates a "READING AROD" signal, serializes the AROD data, sends it into the computer, and generates a "FINISHED AROD READ" signal to be sent to the AROD equipment.
4. The computer calculates the spacecraft's position and velocity from the range and range rate data and the stored locations of the

transponders, and then uses the position and velocity in its guidance computations.

5. The computer transmits the computed position and velocity via the telemetry link, using the Data Adapter and the Output Buffer.

6. The computer sends commands to the AROD transponders via the AROD command link, using the Data Adapter and the Buffer Register, and a PIO-AROD OUT instruction.

7. The computer receives data from the transponders via the Data Adapter and the Digital Input Multiplexer.

1.3.2 Data Adapter

To achieve this flow of information some (relatively minor) modifications to the Data Adapter would have to be made. In essence, they would consist of providing a new set of input lines to the Digital Input Multiplexer, a new set of output lines, probably from the Buffer Register, and synchronization signals to be sent to the AROD equipment.

The implementation currently under consideration for the interface between the Data Adapter and the AROD equipment would transfer the AROD data in ten 26-bit (parallel) words. The 26 input lines carrying data from the AROD equipment would be connected into 26 Discrete Input circuits. The DI circuit outputs would be connected to AND circuits whose other "legs" are activated when a PIO instruction (with the AROD address) is received from the computer and appropriate timing pulses occur. The outputs from the first 13 AROD AND's are connected to the first 13 latches in the Digital Input Multiplexer; the outputs from the second 13 AROD AND's are also connected to the first 13 latches in the DIM. On decoding a PIO-AROD instruction the Data Adapter generates a "READING AROD" signal, which is sent to the AROD equipment just prior to the reading of the data in the AND's, for synchronization purposes. (Other synchronization signals may also be transmitted—e.g., a 4 cps square wave—to permit utilization of existing storage registers in the AROD equipment.) The first 13 AROD AND's are then activated to read data into the DIM; these 13 bits are subsequently serialized in the Serializer and transferred to the computer in the first 13 bit positions. The second 13 bits are then read into the DIM (by activating their AND's), serialized and transferred to the computer in the second 13 bit positions. A "FINISHED AROD READ" is then generated and sent to the AROD equipment. (This process will be repeated 10 times under direction of the computer to read in the 10 26-bit AROD words constituting a "frame").

Another function which the Data Adapter may be called upon to perform is to transfer computer-generated commands to the AROD command link. These commands, which turn on (and off) specified transponders, will probably require a new set of 26 AND gates attached to the 26 latch outputs from the Buffer Register. (The AND's could be located in the AROD equipment also.) These AND gates would be activated when the Data Adapter decodes a computer-generated PIO-AROD OUT instruction.

Several unresolved issues related to the interface design remain for further analysis during the next quarter. These issues are generally concerned with the nature of the information and synchronization signals crossing the interface.

1.3.3 AROD Equipment

The AROD data outputs must exist in some stored form within the AROD equipment if a non-interrupt mode of inputting via the Data Adapter is to be achieved. The manner of implementation of the interface essentially depends upon whether this storage is associated directly with the output of any of the eight (4 for range, 4 for Doppler count) extraction operations or is a separately mechanized entity.

The latter approach would require a buffer storage of the order of 260 bits, which could be jointly used in an independent and asynchronous manner by the telemetry system and the Data Adapter. The use of such a buffer would allow complete asychronism between the AROD data extraction operations and the requests from other equipments for current AROD data frames. A buffer storage of this type would be essentially a word-organized, NDRO memory implemented with N latches, N input gates and N output gates if the gates were controlled in groups of 26 bits. The timing and synchronization requirements of this approach to implementation of the interface would be a minimum.

A buffer so organized could be very profitably implemented with multiaperture magnetic core elements due to the low data rates involved. Some of the outstanding advantages of such a mechanization, as compared to transistor circuit latches plus diode gating (for example), stem from greatly reduced power consumption (low data rate) and much higher reliability due to markedly decreased active element component count. A more compelling advantage relates to the ground loop isolation problems commonly encountered in complex space systems. Complete ground (DC, Signal, and Power) isolation is readily achieved between all interfacing equipments (and associated systems consequently) involved—AROD, Telemetry, and Data Adapter. The above implementation benefits accrue directly from the inherent "transformer-coupled" nature and pulse signal structures of magnetic digital devices.

However, if certain concessions can be made, it is feasible to depend only upon the register storage inherent in the extraction or measurement circuits, at some expense in timing and synchronization difficulties. Since computer requests to the DA for AROD sensor output data may be on a one-word-at-a-time basis, repeated as many times as necessary to gather a full frame, the timing signals from the DA to the AROD would be of the nature of discrete signals, (e.g. "READING AROD"). In such a non-buffered system, however, anticipation timing signals would be required to guarantee that a static (though possibly stale) data output is available when the computer desires access at some time in its program. These signals, plus telemetry timing, would have to be suitably interlocked with the timing of the data extraction operations to insure data validity.

The output access gating for such a "non-buffered" approach to permit transfer to both telemetry and Data Adapter, would be organized in a similar manner as for a buffer storage (with additional provisions for interlocking). A reasonable assumption concerning the registers containing the digital number resulting from the extraction processes is that they could most probably be of some form of hybrid microelectronic transistor logic, such as IBM's ULD. Two sets of parallel gating to telemetry and the DA (with the computer having priority) could then be implemented with the latches comprising the extraction equipment registers. This approach means, however, full bit-parallel word transmission by means of "level" signals. Consequent impact on ground loop isolation would be less than desirable when contrasted to an interface mechanized on a pulse signal basis with suitable transformer coupling. These points will be given further consideration in the next quarter.

Section 2

OCEANBORNE TRANSPONDERS

2.1 BACKGROUND

The development of useful oceanborne AROD transponders depends upon proving techniques to satisfy three major requirements, namely:

1. Accurate positioning of oceanborne platforms with respect to points on land, for example, Cape Canaveral.
2. Accurate determination of the platform's position and velocity with respect to its initial assigned location.
3. Highly stable ocean platforms.

The ocean environment found in the transponder's operational location will markedly affect the platform's design. In this study, emphasis is on a sector from 72° to 105°, measured from north, with a vertex at Cape Canaveral and a radius of 3500 kilometers (1900 nautical miles). Typical sea depths in this area are about 3000 fathoms (18,000 feet), but there are a few seamounts rising to much lower depths. These seamounts are significant because static position errors of moored platforms increase with depth. Wave heights, during a complete year, are less than 12 feet, 95% of the time. Also, 95% of all wave periods, in all seasons, are less than 13 seconds. Details of the ocean environment are presented in paragraph 2.3.1, which is concerned with taut lines.

The transponder platform payload is expected to consist principally of energy storage. To estimate this requirement, a platform servicing cycle period of not less than six months was assumed, with as much as 100 hours of AROD operation during this time. Energy sources for the platform are discussed in paragraph 2. 7.

Since system requirements have not been firmly established, and to better understand the relationship among performance, complexity, and cost, a range of performances is being investigated. Position errors may have two components; one due to the land referencing technique, the other associated with the bottom referencing system. A well designed system will balance errors and costs.

Bottom referencing and platform combinations with position errors ranging from 10 to 200 meters are being considered. The platform should be as nearly stationary as possible. The range of velocities being emphasized is from 0. 05 to 2. 0 meters per second measured at the antenna phase center.

Vertical errors of up to 2° will probably be acceptable. This verticality is needed to avoid multipath interference from the ocean's surface, and to maintain coverage down to elevation angles of 5° above the horizon.

2. 2 PROMISING APPROACHES

For reliable, low cost operation, certain desirable features should be sought in an AROD transponder platform design. Some of the most important features are:

1. Unmanned.
2. No platform propulsion.
3. Passive referencing to the bottom.
4. Obviate the need to transmit position and velocity data to the spacecraft.

The number of man-hours required for AROD operation will strongly affect the system's cost. Vessels that have propulsion for station keeping will almost certainly be manned, and therefore will be expensive to operate. Active referencing to the bottom requires additional electronic complexity, plus ocean bottom acoustic devices, which are expected to have lives limited to six months to a year. The data derived from active referencing may be used to provide:

1. Go/no-go status signals for transmission to shore. These signals would simply indicate whether or not the platform was located within operational specifications.
2. Updated transponder position and velocity data for transmission to the spacecraft and/or shore.
3. Correction control signals to propulsion units.

Land, sea, and air; stationary and moving platforms are tabulated and rated in Table 2. 1. Islands rate highest with respect to the above listed desirable features. Unfortunately, there are not enough of them in the right places. If only one island is used, the AROD base line must be relatively short, but it can be very accurate and there will be no transponder velocity errors. Bermuda is in the area of immediate interest. Within the island, a baseline 15 miles long can be established which would provide more than half of the coverage needed for the presently planned trajectories.

If one of the tentative Bermuda transponders were moved to the Navy's Argus Island (a tower built on the Plantagenet bank 25 miles southwest of the main island), the line could be extended to 40 miles.

Table 2. 1

COMPARISON OF OCEANBORNE TRANSPONDER PLATFORMS

	Platforms \ Features	Unmanned	No Propulsion	Passive Referencing	No Data Transmission
Stationary	Land				
	Island	Yes	Yes	Yes	Yes
	Sea				
	Buoy	Yes	Yes	Maybe***	Maybe***
	Ship	No	No	No (FCC)*	No
	Air				
	Blimp	No	No	No (GCC)**	No
	Helicopter	No	No	No (GCC)**	No
Moving	Land	← Not Applicable →			
	Sea				
	Ship	No	No	No (FCC)*	No
	Air				
	Airplane	No	No	No (GCC)**	No
	Blimp	No	No	No (GCC)**	No
	Helicopter	No	No	No (GCC)**	No

* Fair central control, see text.
** Good central control, see text.
***Active referencing and data transmission will be required only for accuracies better than 50 meters.

The second best choice is a buoy-mounted configuration. This would be passively referenced to the bottom with a mooring line. It appears that active referencing (acoustic) will be needed to obtain errors of less than 50 meters. This necessitates the transmission of position and position rate errors to the spacecraft.

If very accurate relative spacing on an intermediate length base line is desired, and if manned, propelled vehicles can be used, along with position and rate transmission, then the central control vehicle concept is very attractive. This is a generalization of the so called "mother ship" approach. In this concept, a single central control vessel (a ship or aircraft) acts as a common reference to a number of transponder-bearing vehicles. Airplanes, blimps, and helicopters are rated "good central control" (GCC), because of the relatively long line-of-sight base lines available through high altitudes and the relatively short periods of manned operation needed. Ships are rated "fair central control" (FCC) because of the shorter line-of-sight available between surface vessels and the long periods of manned operation involved.

If an early operational date had to be met, the best approach would be to use ships because of their immediate availability. Since low altitude trajectories are of greatest interest, simple "shaped" omnidirectional antennas could be used. These would be light weight and easy to stabilize. Each ship would be outfitted with an inertial platform for antenna control to compensate for roll and pitch motion of the vessel. Costs would be expected to be high because of the long periods of manned operation necessary.

The principal studies during the past quarter have been concerned with the unmanned buoys because of their expected high performance and low cost. The paragraphs that follow describe suitable bottom referencing techniques and platform design.

2.3 BOTTOM REFERENCING

2.3.1 Taut Lines

In the moored buoy transponder platform concept; if the mooring rope is adjusted to a length shorter than the depth of the water at the anchoring site, the line remains taut at all times. The static tension, T, will be equal to the difference between the vessel's buoyancy, B, and its weight

$$T = B - W \text{ (lb.)}. \tag{2.1}$$

An advantage of taut line operation is that the vessel can be designed to be essentially undisturbed by most surface waves. Because of the extreme water depth there will be no wave effects from the bottom. The widely prevalent depth in the region of interest is 18,000 feet. Under these circumstances waves can be represented by Gerstner's trochoidal model (see Figure 2.1)[1]. In this representation individual particles of water appear to be moving in a circular path with a radius R. The uppermost curve is a cycloid formed by rolling a circle along the imaginary dashed line. The actual water surface may be any one of the lower solid lines shown in the diagram. The radius of circular motion at the surface is designated as R_0. Whereas, in theory, the ratio of wave length, λ, to wave height, H, could be as small as π, empirical data indicates that the ratio never is less than 7; usually it is much greater. Statistics presented by the U. S. Navy and the Weather Bureau indicate that 95% of the time wave heights will be less than 12 feet for all periods, and similarly 95% of all wave periods, P_W, will be less

[1] Lamb, H. Hydrodynamics, 6th Edition, 1932. Republished by Dover Publications, Inc.

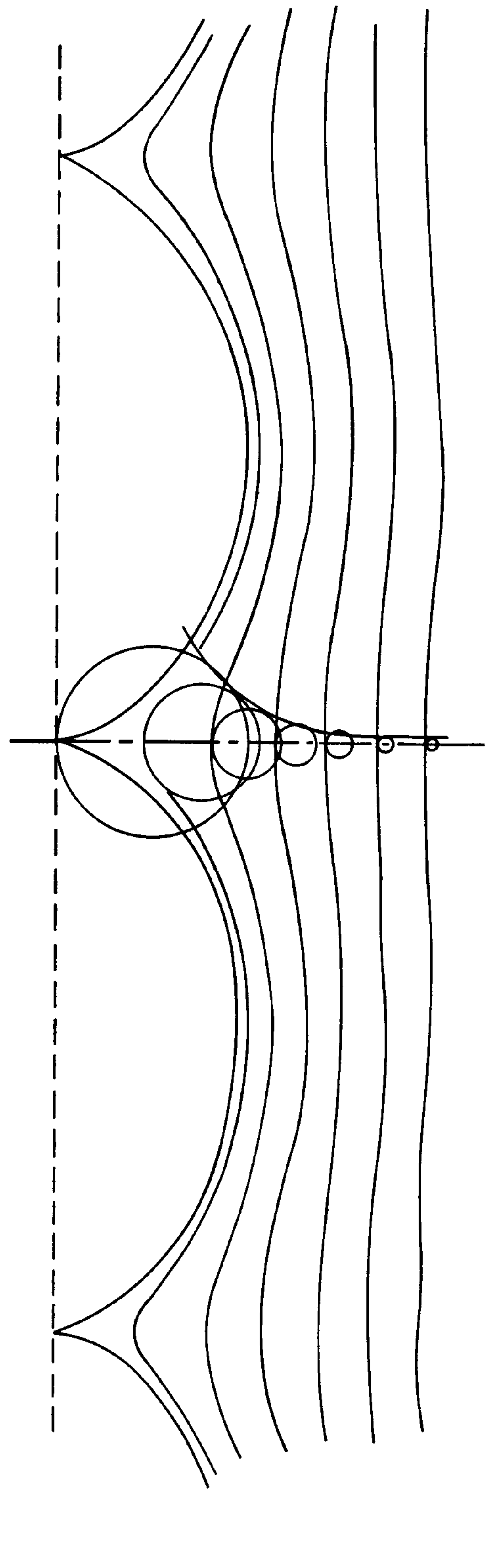


Figure 2.1 TROCHOIDAL WAVES

than 13 seconds for all wave heights (see Figure 2.2)[2]. Wave lengths, in feet, are related to wave periods, in seconds, by the following relationship:

$$\lambda = 5.12\, P_W^2 \text{ (ft.)}. \tag{2.2}$$

The circular motion of particles below the surface at a depth, y, is given by:

$$R = R_o e^{\frac{2\pi}{\lambda} y} \text{ (ft.)}. \tag{2.3}$$

At a depth equal to $\lambda/2$, R is about $0.04\, R_o$; and at λ, R is less than $0.002 R_o$. Thus by keeping the buoy below the surface all but the longest waves are effectively eliminated, i.e., depth performs a function analogous to a low pass filter.

A taut-line moored buoy will have a static position error with respect to the bottom anchoring point to ocean currents. Maps are available indicating surface currents for each month of the year. With the exception of the Gulf Stream, which stays quite close to the coast of Florida, the maximum rate is about 0.7 knots. Very little detail is known about subsurface conditions. Generally however, surface conditions extend to a depth of a hundred feet or so, and at greater depths currents with markedly different directions may exist with velocities between 0.1 and 0.3 knots.

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[2] Climatological and Oceanographic Atlas for Mariners, Vol. 1, North Atlantic, 1959, U. S. Department of Commerce, Weather Bureau and U. S. Department of the Navy, Navy Hydrographic Office.

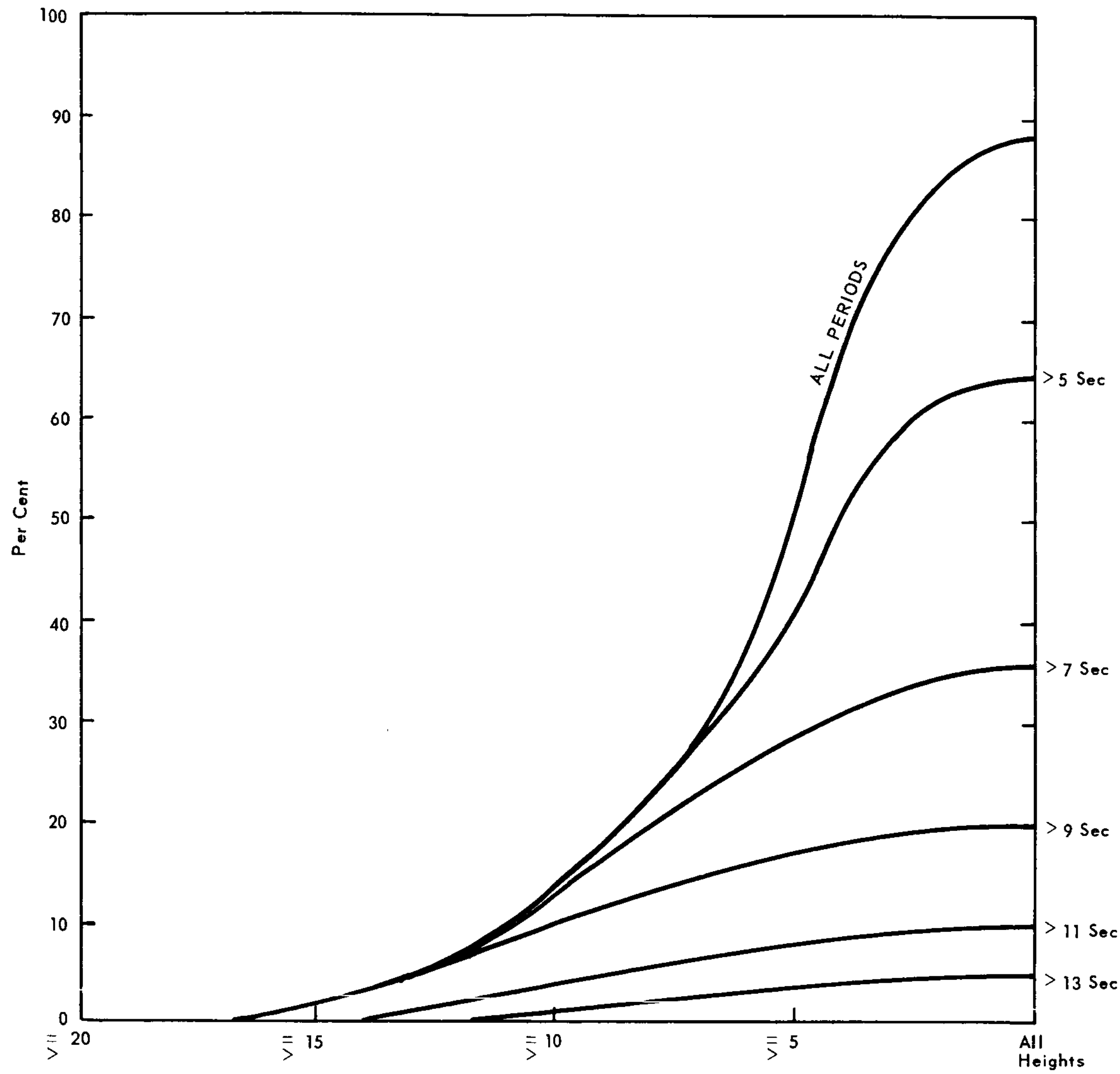

Figure 2.2 WAVE PERIOD AND HEIGHT

If a neutrally buoyant (density = 1) rope is used, so that there will be neither sagging nor floating of the line when the buoy is displaced from its zero error position, and if the major part of the drag, D, due to currents is on the buoy, then the amount of displacement error, ϵ, with a line of length, L, is

$$\epsilon = L\left(\frac{D}{B-W}\right) \quad \text{(ft.)}. \tag{2.4}$$

See Figure 2.3. Drag is in effect being balanced by a static force, F_s, which can be found from

$$F_s = \frac{\epsilon}{L}(B-W) \quad \text{(lb.)}. \tag{2.5}$$

This force will be used later in the determination of the free motion of the buoy.

It should be noted that ϵ is directly proportional to L. Therefore, to reduce position errors as much as possible, mooring sites should be in shallow water wherever feasible. In the region of interest there are some potential sites worthy of further investigation. The approach to the mid-Atlantic ridge is in some places about 9000 feet below the surface. Also, there are occasional seamounts such as those off Bermuda at a depth of 150 feet; and a little further east, one with a depth of 5500 feet; at 47°W, 35°N one at 3600 feet depth; at 59°W, 21°N Echo Bank is at a depth of 200 feet; and near 77°W, 33°N, an off shore seamount rises to a depth of 340 feet. See the map in Figure 2.4.

The configuration shown in Figure 2.5 is similar to a pendulum, and therefore will have a natural frequency. Assuming zero mass for the line and ignoring the drag of the rope moving through the water, the undamped natural frequency, f_p, and its period, P_p, can be found. This is done by summing the kinetic force, Ma (mass multiplied by

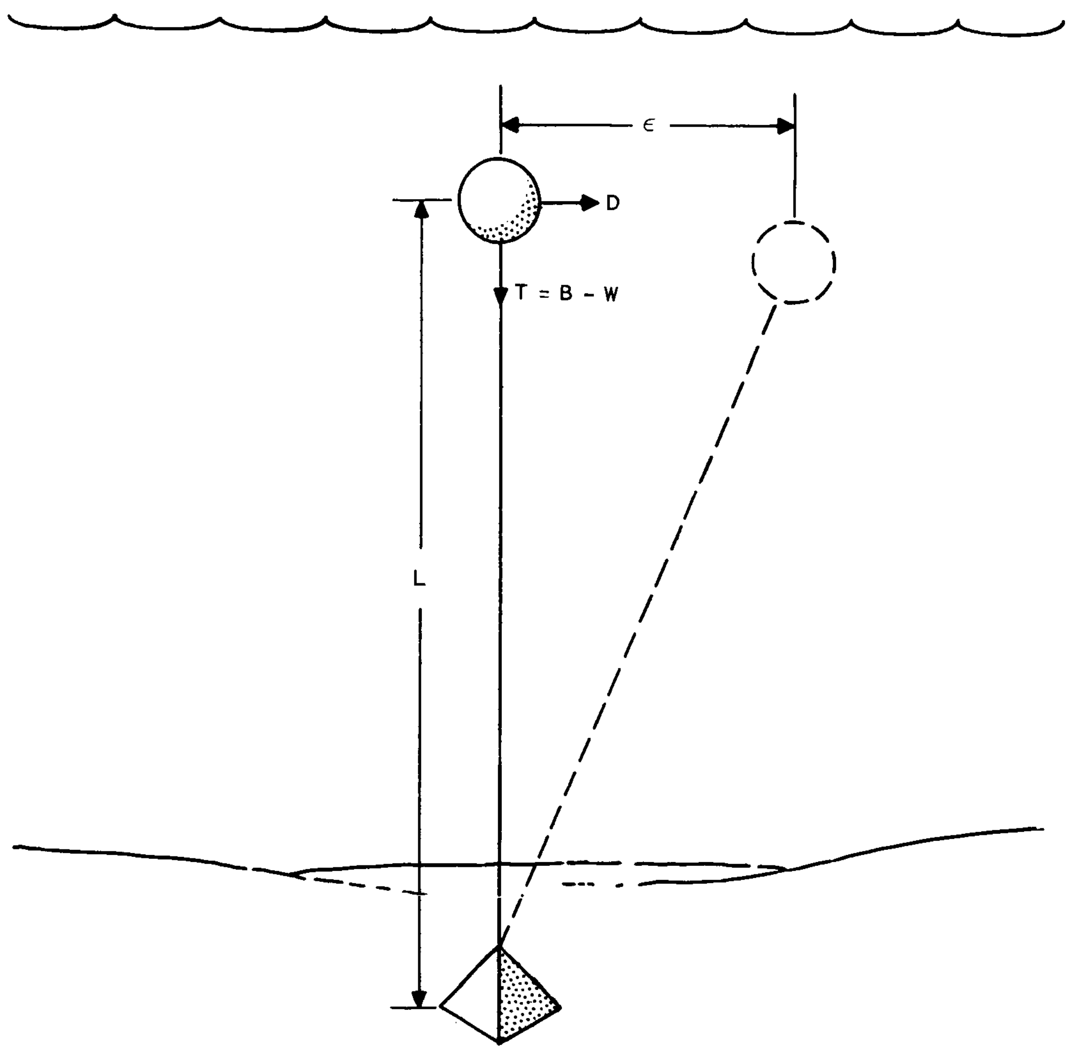

Figure 2.3 DRAG DISPLACEMENT

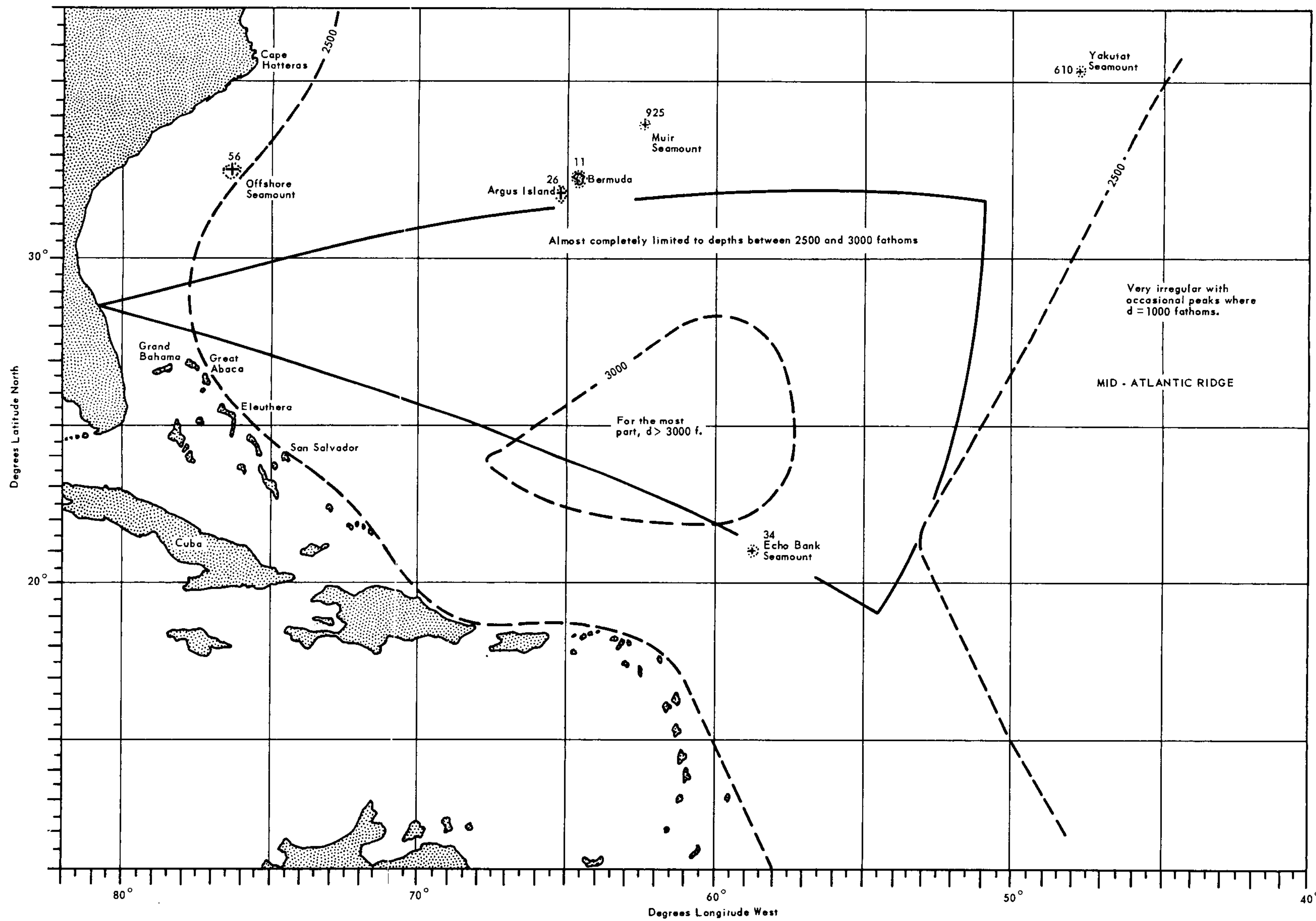

Figure 2. 4 KNOWN SEAMOUNTS AND DEPTH TRENDS

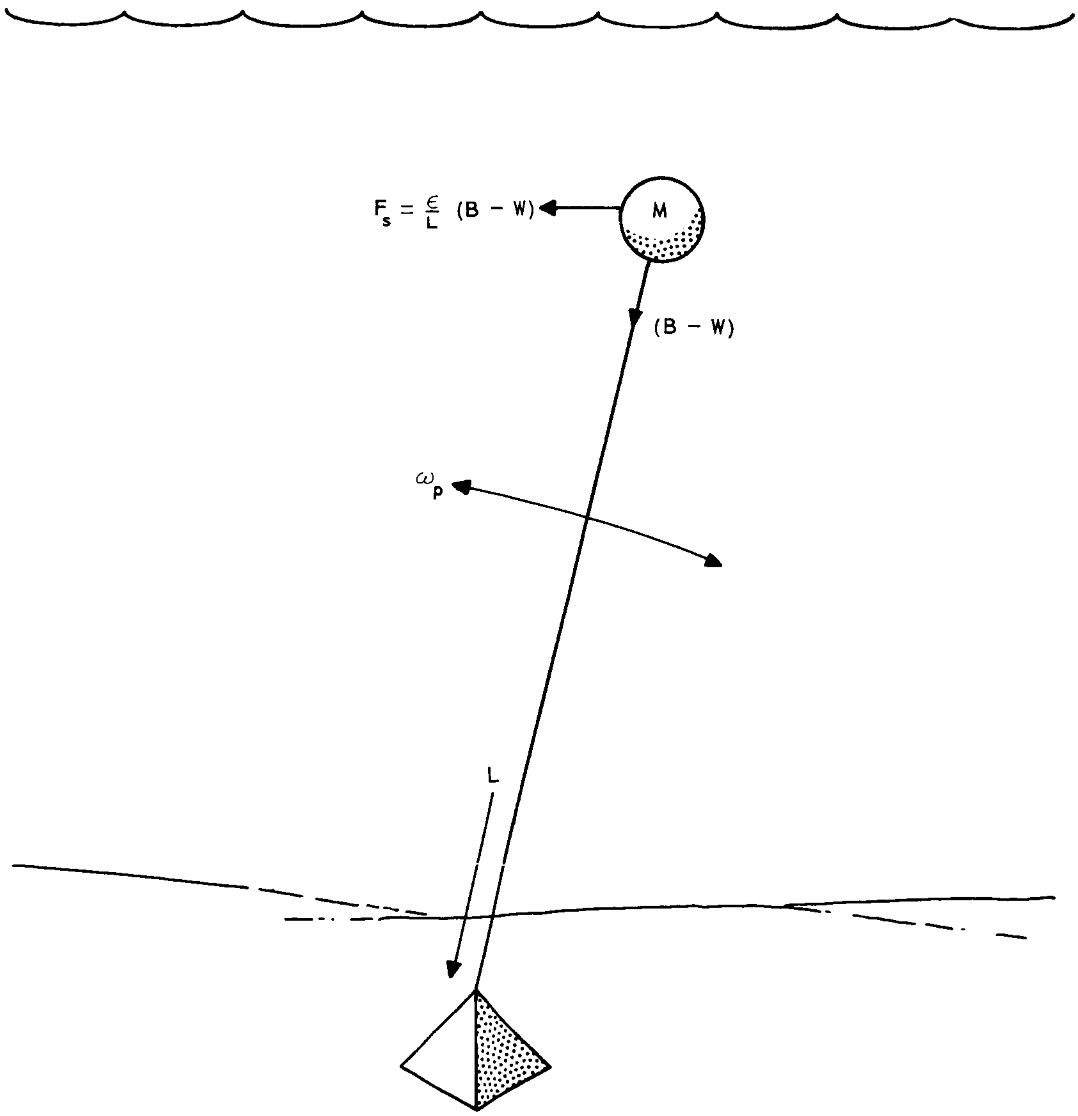

Figure 2.5 PENDULUM MOTION OF BUOY

acceleration), and the static force from equation (2. 5), and setting the combination equal to zero.

$$Ma + \frac{\epsilon}{L}(B - W) = 0$$

Replacing a with $(j\omega)^2 \epsilon$ and solving for ω leads to formulas for f_p and P_p.

$$M(j\omega)^2 \epsilon + \frac{\epsilon}{L}(B - W) = 0$$

$$f_p = 0.903 \sqrt{\frac{\left(B/W\right)-1}{L}} \quad \left(\frac{\text{cycles}}{\text{sec.}}\right) \tag{2. 6a}$$

$$P_p = 1.11 \sqrt{\frac{L}{\left(B/W\right)-1}} \quad (\text{sec.}) \tag{2. 6b}$$

Typical periods would be several minutes long.

Steps can be taken that will improve position accuracy beyond that achievable with the basic one rope taut line. Using multiple lines (of neutral buoyancy) the position of the buoy can be fixed as the intersection of spheres (Figure 2. 6). The simplicity, passive referencing, and freedom from need to telemeter data make the multiple taut line approach very attractive.

With knowledge of buoy drag characteristics, and telemetry data from a compass and an ocean current meter, an "open loop" calculation can be made to determine the magnitude and direction of the buoy's displacement. See Figure 2. 7.

2. 3. 2 Acoustic Referencing

Acoustic referencing devices placed on the ocean bottom can be used to measure displacements. This data could then be telemetered to the spacecraft and/or the shore. See Figure 2. 8. Using acoustic frequencies in the region of 10 to 20 kc/s, acoustic powers of about

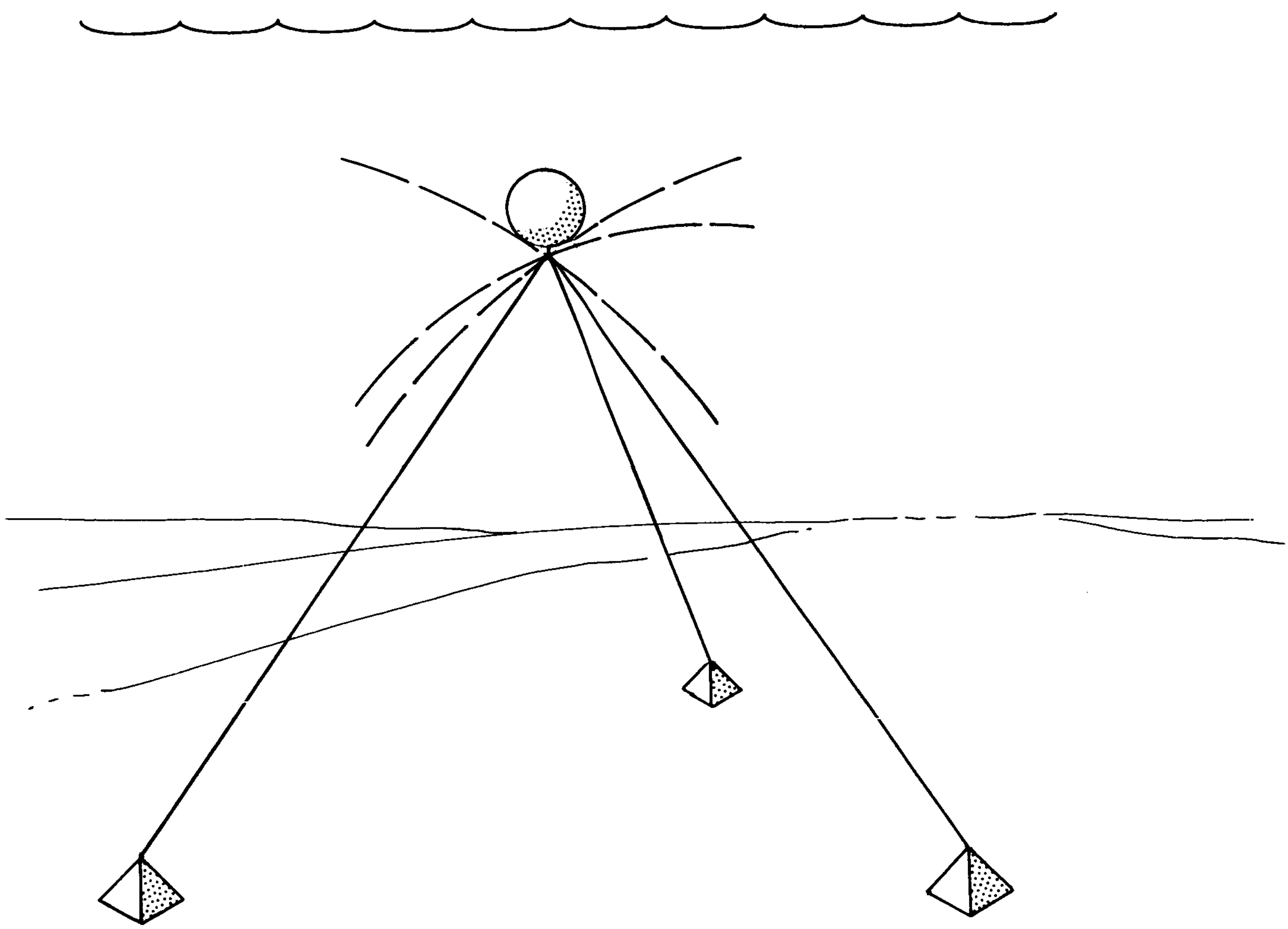

Figure 2. 6 MULTIPLE TAUT LINES

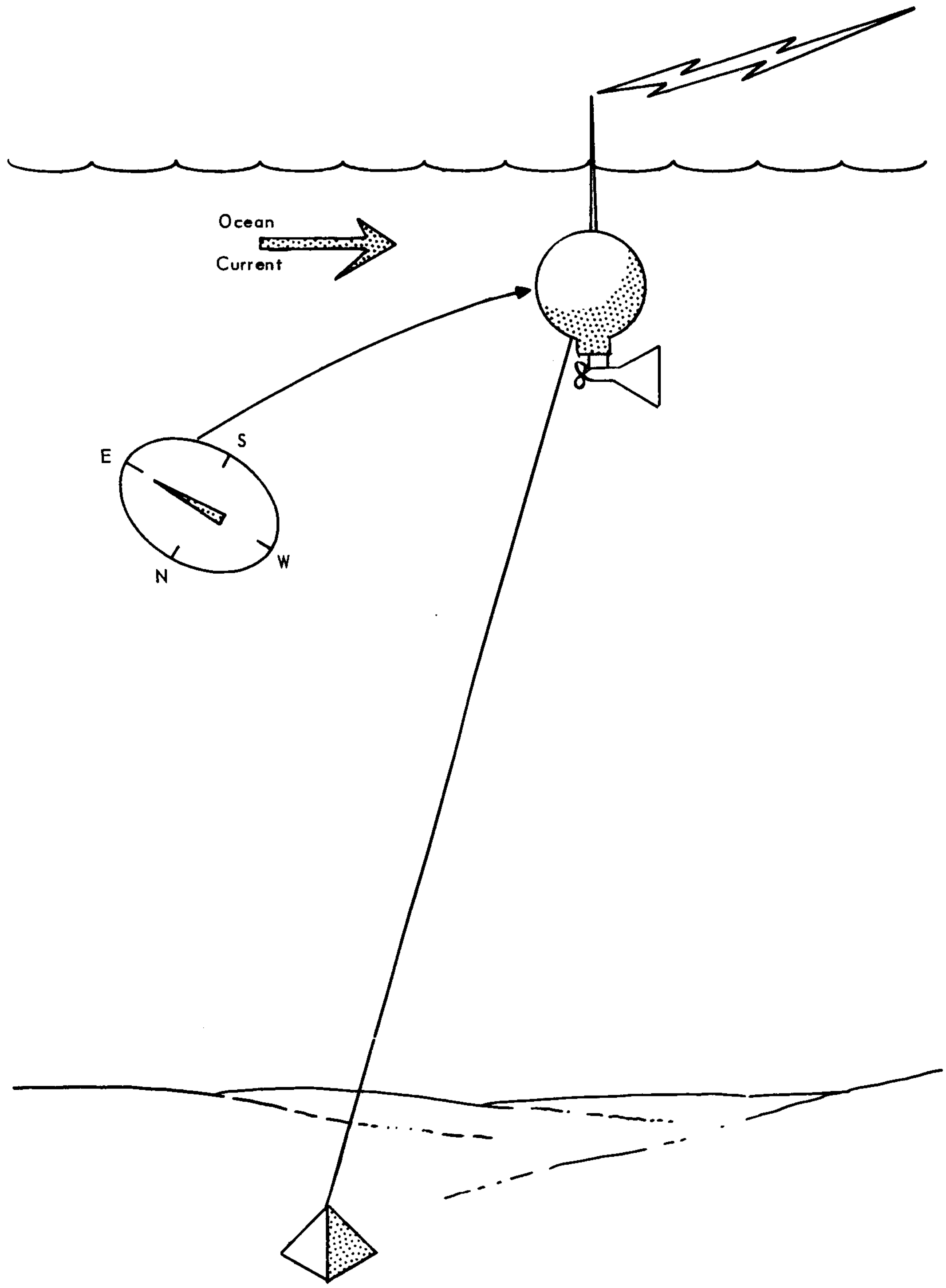

Figure 2.7 OCEAN CURRENT AND DIRECTION TELEMETRY FROM TAUT LINE BUOY

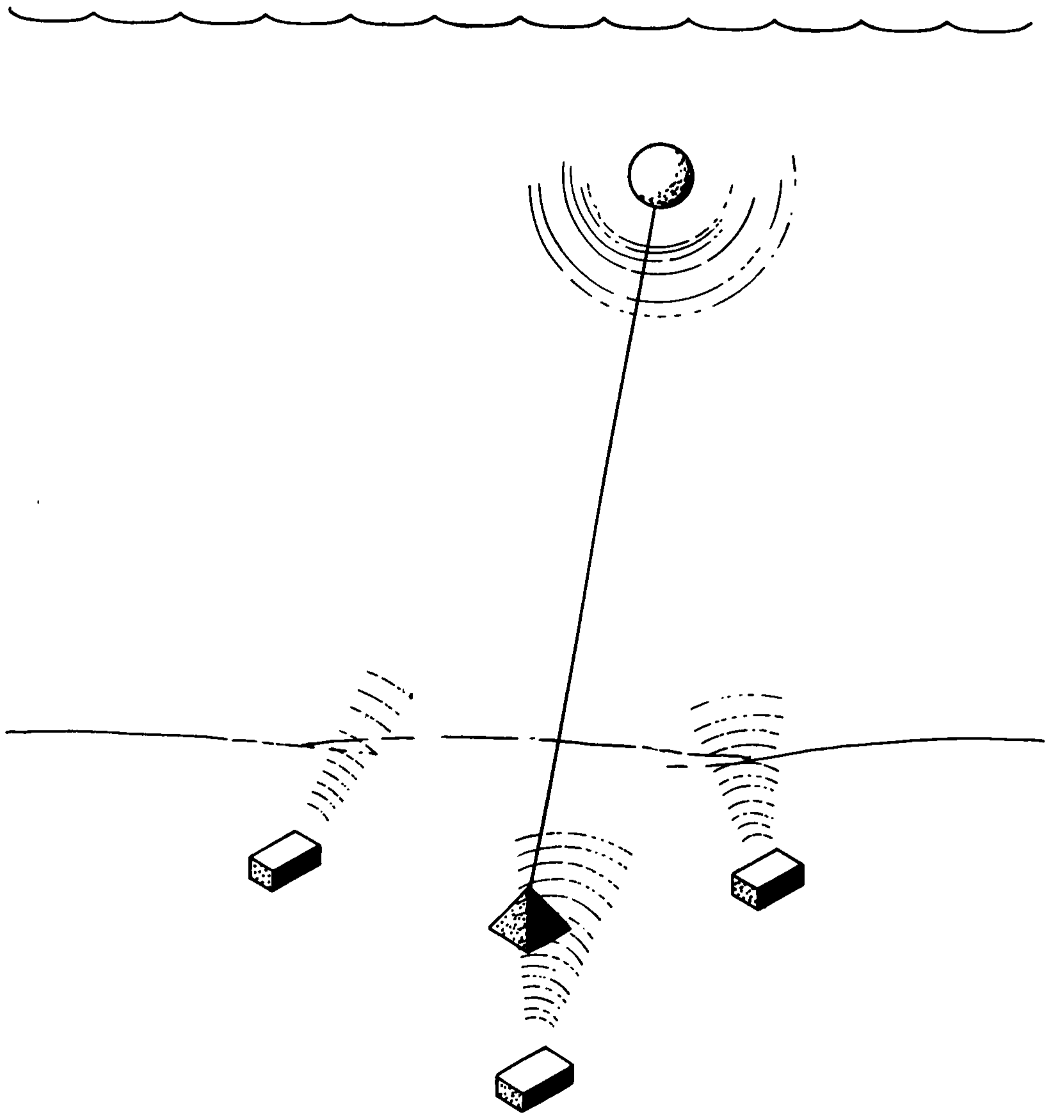

Figure 2.8 ACOUSTIC BOTTOM REFERENCING

10 watts, and sea state 4 (corresponding to an environment exceeded 5% of the time in the area of interest) for the noise background, preliminary estimates of position accuracy have been obtained; the resulting total errors range between 10 and 25 meters.

An evaluation of velocity measurement by Doppler shifts is underway, as well as a study of the possibility of measuring platform motion with inertial instruments.

The acoustic instrument arrangement studied so far has had the sources and receivers on the buoy and a set of transponders on the bottom. The long two-way transmission time (about 10 seconds) has been a major handicap, especially for obtaining meaningful velocity data. If the bottom devices were connected to the buoy by wire the acoustic path would be one way instead of two. This would offer an important improvement, since velocity measurement delays would be greatly reduced.

2.4 OCEANBORNE PLATFORMS

The subsurface type platform described in the paragraph on taut lines has received principal attention. Conceptually, a buoy would be held below the surface by a rope fastened to the ocean bottom. Anchorage at a depth below the surface provides an isolation from turbulent surface conditions. Additional isolation from wave motion can be gained by designing the buoy with a very sluggish behavior. A long pole having low drag would be mounted on top of the buoy, and would pierce the water's surface. The AROD transponder antenna would be placed on top of the pole. To stay within the required 2° of vertical, the buoy should be made as insensitive as possible to unbalanced torques. Or, alternatively, a small gimballed platform may be used. Figure 2.9 shows a general arrangement of center of gravity, G, center of buoyancy, B,

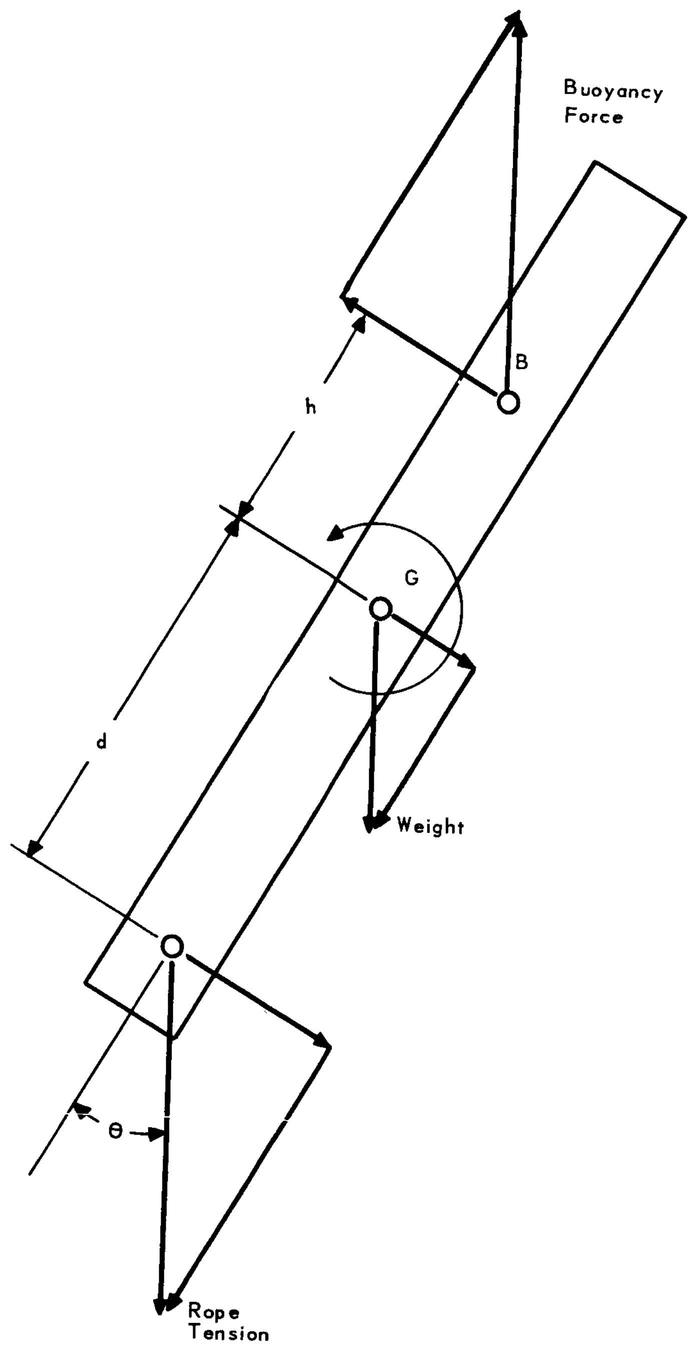

Figure 2.9 SCHEMATIC OF TORQUE ACTING ON THE BUOY

and T, the point at which the rope is attached. B is shown above G at a distance h, and T is below G at a distance d. Summing torques around the center of gravity, namely, the kinetic torque, $I\alpha$ (moment of inertia times angular acceleration), and static torques produced when the buoy is tipped through a small angle θ, and setting the combination equal to zero, it is possible to find the undamped free motion of the submerged buoy. This is similar to finding the resonant frequency of a coil and capacitor while ignoring Q.

$$I\alpha + Bh\theta + d\,(B-W)\,\theta = 0$$

In place of I, substitute $\left(\frac{W}{g}\right) k^2$ (where k is the buoy's radius of gyration). Also, substitute $(jw)^2\,\theta$ for α

$$\left(\frac{W}{g}\right)(jw)^2\,\theta + Bh\,\theta + d\,(B-W)\,\theta = 0$$

From this f_B, P_B and k can be found.

$$f_B = \frac{0.903}{k}\sqrt{\left(\frac{B}{W}\right)h + \left(\frac{B}{W} - 1\right)d} \quad \left(\frac{\text{cycles}}{\text{sec.}}\right) \qquad (2.7a)$$

$$P_B = 1.11\,k\sqrt{\frac{W}{Bh + (B-W)\,d}} \quad (\text{sec.}) \qquad (2.7b)$$

$$k = 0.903\,P_B\sqrt{\frac{B}{W}h + \left(\frac{B}{W} - 1\right)d} \quad (\text{ft.}) \qquad (2.7c)$$

Attachment of the rope to either the center of gravity or the center of buoyancy (that is, setting d equal to 0 or -h) simplifies the above expressions.

$$d = 0 \begin{cases} f_B = \dfrac{0.903}{k} \sqrt{\dfrac{B}{W} h} & \left(\dfrac{\text{cycles}}{\text{sec.}}\right) \quad (2.7d) \\[2ex] P_B = 1.11\, k \sqrt{\left(\dfrac{W}{B} \times \dfrac{1}{h}\right)} & (\text{sec.}) \quad (2.7e) \\[2ex] K = 0.903\, P_B \sqrt{\left(\dfrac{B}{W}\right) h} & (\text{ft.}) \quad (2.7f) \end{cases}$$

$$d = -h \begin{cases} f_B = \dfrac{0.903}{k} \sqrt{h} & \left(\dfrac{\text{cycles}}{\text{sec.}}\right) \quad (2.7g) \\[2ex] P_B = 1.11\, k \sqrt{\dfrac{1}{h}} & (\text{sec.}) \quad (2.7h) \\[2ex] K = 0.903\, P_B \sqrt{h} & (\text{ft.}) \quad (2.7i) \end{cases}$$

The center of buoyancy can also be adjusted, but that will not be discussed. It was assumed, in the above development, that the tension B - W always acts in the same direction and is constant. This is not strictly true since the buoy can be displaced by drag forces produced by ocean currents and tension changed by vertical current components. By attaching the rope to the center of rotation, changes in the direction of rope tension can be eliminated from equations for rocking of the buoy. If not restrained, a body rotates around its center of gravity. Therefore, G is a good place to attach the mooring line. Stated another way, unless $d = 0$, rocking of the buoy can start the line moving, and conversely movement of the line can rock the buoy.

Differences in drag between the top and bottom of the buoy when steady ocean currents are present, will result in an unbalanced steady torque, ΔT_s, which will be countered by correcting torques.

A steady state angular error, with sensitivity θ_{ss}, will be present, however.

$$\Delta T_s = Bh\theta + (B-W)\,d\,\theta$$

$$\theta_{ss} = 57.3 \times \frac{\theta}{\Delta T_s} \qquad \left(\frac{\text{deg.}}{\text{lb. x ft.}}\right)$$

$$\text{(general)} \quad \theta_{ss} = \frac{57.3}{Bh + (B - W)\,d} \qquad \left(\frac{\text{deg.}}{\text{lb. x ft.}}\right) \tag{2. 8a}$$

$$(d = 0) \qquad = \frac{57.3}{Bh} \tag{2. 8b}$$

$$(d = -h) \qquad = \frac{57.3}{Wh} \tag{2. 8c}$$

If P_B and θ_{ss} are specified, new equations can be written for the radius of gyration by combining (2. 7c) with (2. 8a), (2. 7f) with (2. 8b), and (2. 7i) with (2. 8c). In all cases the formula is

$$k = \sqrt{\frac{6.83\, P_B}{W\,\theta_{ss}}} \qquad \text{(ft.)} \tag{2. 9}$$

It can be seen that if W is fixed, and P_B is required to be large, and θ_{ss} is required to be small; k must be large. This suggests concentrating mass at the ends of long, stiff, low mass arms as shown in Figure 2. 10. The arms would have a length approximately equal to k. In this case

$$k = 46.6\, P_B^{\,2}\, \frac{\Delta D_S}{W\,\theta} \qquad \text{(ft.)} \tag{2. 10}$$

Where ΔD_s is the steady unbalanced drag.

With k' defined as k divided by $46.6\, P_B^2\, \Delta D_S / W$, that is, normalized radius of gyration, Figure 2. 11 was plotted to show the sensitiviy of k to demands for verticality. Note that there are regions of high and low sensitivity.

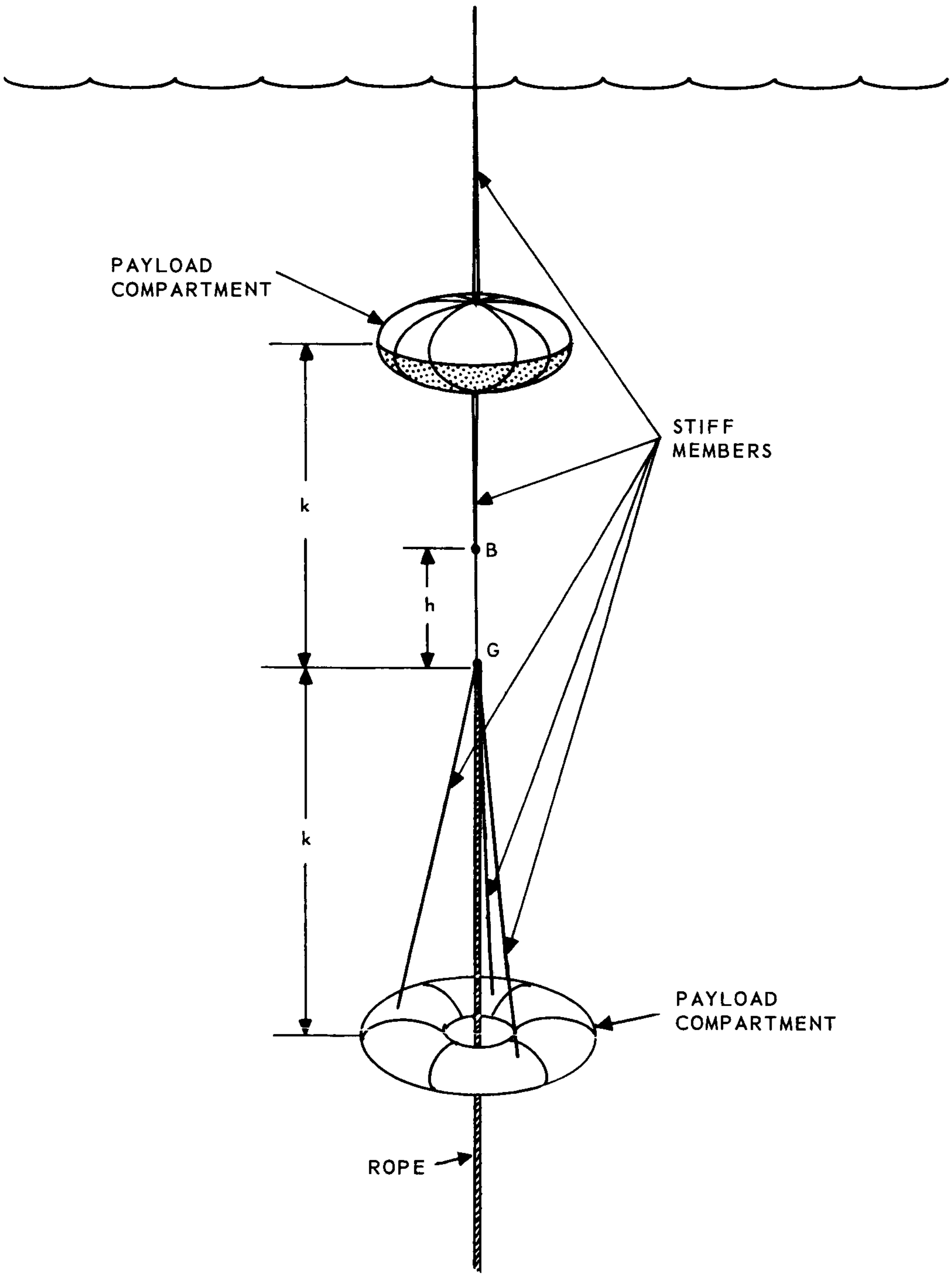

Figure 2. 10 SCHEMATIC OF BUOY

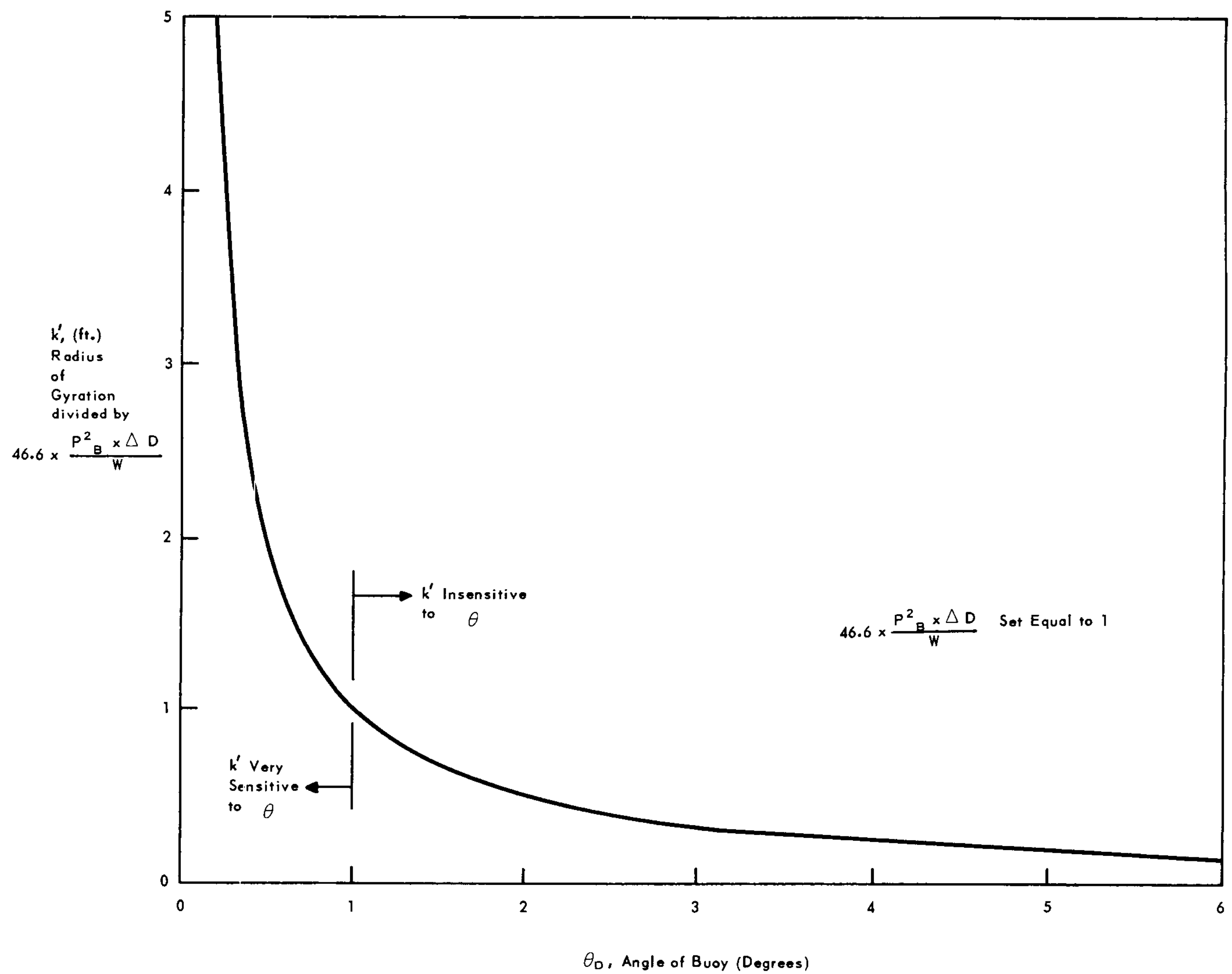

Figure 2.11 STEADY DEFLECTION OF BUOY FROM UNBALANCED DRAG

2.5 SHORE REFERENCING

Part of the necessary data has been gathered for calculating the performance of several long-range, high-accuracy position fixing systems that may be used for referencing transponder locations to the shore. Absolute accuracy, cost, and the time required for each measurement are of interest. Evaluation of the shore referencing techniques has been postponed until the second quarter when more complete information is expected to be available.

2.6 STATUS OF THE PLATFORM WITH RESPECT TO MARITIME LAW.

The status of such platforms is being discussed at several meetings in Europe this fall. At present no requirement exists for marking or warning equipment for buoys in international water. Unmanned platforms are, however, subject to seizure and the owner is subject to suit for damage resulting from collision, regardless of warning precautions taken. Therefore, it is prudent to mark the buoys with high visibility paint (orange and white), a 100 candlepower white light flashing 0.4 seconds every 4 seconds, and an array of corner reflectors for detection by ship radars operating at a wave length of 20 centimeters.

2.7 ENERGY SOURCES FOR THE PLATFORM

Although there is considerable interest in developing a substitute for common Carbon-Zinc air depolarized batteries, nothing is currently in use which can match their cost, weight, and reliability. If the AROD equipment can operate on 250 watts, 200 hours of operation during a year would require 50 kilowatt hours of power. A 100 candlepower flashing light drawing 2.2 ampere hours per day at 12 volts would consume 10 kilowatt hours per year. For $500 a 60 KWH battery pack is available in a 1400 lb. package supplying 12 volts for 5000 ampere hours.

Wave action generators have been developed capable of producing 275 watts in 6 foot seas. But because little power is available during calm seas, and because the generator would add drag-induced buoy position errors, this source is not attractive. As an alternative, a thermoelectric propane powered generator system could be used to charge a battery capable of handling 250 watt-hour loads. Such a system is attractive from a fuel cost standpoint for long term use but the weight of the fuel consumed plus the storage tanks, is similar to the battery pack weight. Overall efficiencies of 2.5% have been achieved. This is expected to be doubled in the near future. U. S. Coast Guard experience with ocean buoys favors the battery pack, until the thermoelectric advantage is more pronounced to offset the unknown reliability problem and specialized refueling procedures.

2.8 CONCLUSIONS

The statistics of the ocean environment have been determined from references obtained from the U. S. Weather Bureau and the U. S. Navy. These data have been combined with classical theories of hydrodynamics to determine the forces that will influence an oceanborne platform.

The statistics indicate that 95% of the time wave heights and periods are less than 12 feet and 13 seconds, respectively. Hydrodynamic theory shows that wave length is related to wave period but not to wave height, except to establish a minimum ratio of length-to-height. The decay of wave motion below the surface was found to be exponential and related to wave length (hence wave period). It can be concluded that a platform placed 50 to 100 feet below the surface will be virtually unaffected by all but the longest period waves.

The desire for a reliable, low cost transponder platform caused emphasis to be placed on the unmanned buoy concept. The principal buoy structure could be moored below the surface to avoid waves, and a slim, rigid pole could carry the AROD transponder antenna above the surface. The dimensions and mass distribution of the buoy could be arranged to "filter out" the wave motion remaining at the buoy's depth.

The buoy could be held submerged, and at the same time be referenced to the bottom, by a rope line cut shorter than the water's depth. A neutrally buoyant rope would be used to avoid sagging or floating. Ocean currents would displace the buoy by an amount directly proportional to the line's length, and inversely proportional to the tension in the rope. Surface currents are generally less than 0.7 knots. This suggests the placement of transponders on seamounts wherever possible. A number of potentially useful locations have been found by consulting depth charts. Multiple mooring lines have also been considered, not only for the strength they would add, but also, because, with proper spacing, they could accurately locate a buoy at the intersection of the line lengths. Further improvements in position accuracy, and velocity measurements, can be obtained by the incorporation of an acoustic system that would measure the time of transit between the buoy and the bottom. Several acoustic devices would be placed on the bottom. The resulting error signal could control correcting propulsion units, but more likely the data would be transmitted to the spacecraft and/or the shore.

Because the buoys will be in international waters there is no legal requirement to mark them. The U. S. Coast Guard, however, will probably recommend a bright paint, a light, and a radar reflector.

For energy storage, recommendations from the U. S. Coast Guard are for carbon-zinc cells with air depolarizer. The reason is proven high reliability and low cost. None of the usable higher performance sources currently being tested would offer an order of magnitude improvement. However, results of tests will continue to be monitored.

2.9 PROGRAM FOR THE SECOND QUARTER

Quantitative calculations will be made to determine wave pressures at various depths, and estimates will be made of drag on different parts of several buoy configurations. Position and velocity errors will be calculated for selected buoy configurations and mooring line arrangements, and the improvements available through the use of acoustic devices will be determined.

Techniques for referencing transponder locations to the shore will be compared on the basis of absolute accuracy, cost, and time required for making each measurement.